

BRI

S. I. A.

BRITISH ASSOCIATION
FOR THE ADVANCEMENT
OF SCIENCE

REPORT

OF THE

NINETY-SEVENTH MEETING
(NINETY-NINTH YEAR)



SOUTH AFRICA—1929
JULY 22—AUGUST 3

LONDON

OFFICE OF THE BRITISH ASSOCIATION
BURLINGTON HOUSE, LONDON, W. 1

1930



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TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.O.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.O.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. O. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.O.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, O.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, O.O., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.O.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. O. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.O.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.O.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, O.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.O.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, O.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, O.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.O.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec. R.S.	296	20

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[Continued on p. xii.]

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Asso- ciates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
76	376	33†	331*	28	1316	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
126	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1689	791	15	3138	3944 0 0	1111 5 10	1861
160	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45†	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2616 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.‡	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	288	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[Continued on p. xiii.]

Table of

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.O.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	116	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914, July-Sept.	Australia	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on Tyne .....	.....	164	12
1917	(No Meeting)	} Sir Arthur Evans, F.R.S. {	—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth	Hon. Sir C. Parsons, K.C.B., F.R.S.	235	47
1920, Aug. 24	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.	119	7
1925, Aug. 26	Southampton	Prof. Horace Lamb, F.R.S.	280	8
1926, Aug. 4	Oxford	H.R.H. The Prince of Wales, K.G., F.R.S.	358	9
1927, Aug. 31	Leeds	Sir Arthur Keith, F.R.S.	249	9
1928, Sept. 5	Glasgow	Sir William Bragg, K.B.E., F.R.S.	260	10
1929, July 22	South Africa	Sir Thomas Holland, K.O.S.I., K.O.I.E., F.R.S.	81	1

¹ Including 848 Members of the South African Association.² Including 137 Members of the American Association.³ Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.⁴ Including Students' Tickets, 10s.⁵ Including Exhibitioners granted tickets without charge.

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0	920 9 11	1901
314	86	647	305	6	1620	1644 0	947 0 0	1902
319	90	688	365	21	1754	1762 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0	887 18 11	1904
937 ¹	411	430	181	16	2130	2422 0	928 2 2	1905
356	93	817	352	22	1972	1811 0	882 0 9	1906
339	61	659	251	42	1647	1561 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0	1157 18 8	1908
290 ²	162	789	90	7	1468	1623 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0	963 17 0	1910
349	61	414	81	31	1241	1176 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0	978 17 1	1913
139	4160 ³	539 ⁴	—	21	5044 ⁵	4873 0	1861 16 4 ⁶	1914
287	116	528 ⁴	141	8	1441	1406 0	1569 2 8	1915
250	76	251 ⁴	73	—	826	821 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688 ⁴	153	3	1482	1736 0	410 0 0	1919

Old Annual Regular Members	Annual Members		Transferable Tickets	Students' Tickets					
	Meeting and Report	Meeting only							
136	192	571	42	120	20	1380	1272 10	1251 13 0*	1920
133	410	1394	121	343	22	2768	2599 15	518 1 10	1921
90	294	757	89	235 ⁷	24	1730	1699 5	772 0 7	1922
					Complimentary.				
123	380	1434	163	550	308 ⁷	3296	2735 15	777 18 6*	1923
37	520	1866	41	89	139	2818	3165 19 ⁸	1197 5 9	1924
97	264	878	62	119	74	1782	1630 5	1231 0 0	1925
101	453	2338	169	225	69	3722	3542 0	917 1 6	1926
84	334	1487	82	264	161	2670	2414 5	751 10 0	1927
76	554	1835	64	201	74	3074	3072 10	1259 10 0	1928
24	177	1227 ¹¹	—	161	83	1754	1477 15	1838 2 1	1929

* Including grants from the Caird Fund in this and subsequent years.

⁷ Including Foreign Guests, Exhibitioners, and others.

⁸ The Bournemouth Fund for Research, initiated by Sir O. Parsons, enabled grants on account of scientific purposes to be maintained.

⁹ Including grants from the Caird Gift for research in radioactivity in this and subsequent years to 1926.

¹⁰ Subscriptions paid in Canada were \$5 for Meeting only and others pro rata; there was some gain on exchange.

¹¹ Including 450 Members of the South African Association.

REPORT OF THE COUNCIL, 1928-29.

I. *Presidency of the Association*.—Professor F. O. Bower, F.R.S., has been unanimously nominated to fill the office of President of the Association for the year 1930-31 (Bristol Meeting).

II. *Obituary*.—The Council has had to deplore the loss by death of the following office-bearers and supporters :—

Sir Hugh K. Anderson.

Mr. Douglas Berridge, till lately Recorder of Section L (Educational Science).

Prof. R. A. Berry, who rendered valued service to Section M (Agriculture) as Local Secretary at the recent Meeting in Glasgow.

Prof. G. H. Bryan.

Sir Horace Darwin.

Sir William Boyd Dawkins.

Sir George Fordham, who had accepted the presidency of the Conference of Delegates of Corresponding Societies at Havre, July, 1929.

Dr. J. W. L. Glaisher.

Rev. Dr. H. B. Gray.

Dr. Alex Hill.

Prof. Micaiah Hill.

H.H. the Maharaj Rana of Jhalawar.

Sir Alexander Kennedy.

Sir Hercules Read.

Sir Henry Rew.

Mr. Mark L. Sykes, till lately a member of the Corresponding Societies Committee.

Sir Bertram Windle.

Prof. R. H. Yapp, whose ill-health prevented his occupation of the chair of Section K (Botany) at the Glasgow Meeting.

Prof. Allyn Young, who occupied the chair of Section F (Economics) at Glasgow.

The Council conveyed to Sir Oliver Lodge an expression of condolence on the death of Lady Lodge, and to the Australasian Association for the Advancement of Science on the death of its President, Mr. R. H. Cambage.

III. *Representation*.—Representatives of the Association have been appointed as follow :—

Folklore Society (50th Anniversary)	Prof. J. L. Myres
Gesellschaft Deutscher Naturforscher (Hamburg Meeting)	Prof. G. Barger
National Association for the Prevention of Tuberculosis (Meeting, 1928)	Dr. J. G. Garson
École Centrale des Arts et Manufactures, Paris (Centenary Meeting)	Dr. A. Loir (Havre)
American Association for the Advancement of Science (New York Meeting)	Prof. H. H. Turner
King's College, London, Centenary Service of Thanksgiving, Westminster Abbey	Dr. F. E. Smith

With reference to the attendance of Prof. H. H. Turner as the Association's representative at the New York Meeting of the American Association for the Advancement of Science, the Council has been favoured by

Dr. Burton E. Livingston, Permanent Secretary, with the following extracts from the Minutes of his Council, and remarks :—

Professor Herbert Hall Turner, Savilian professor of astronomy in Oxford University, was introduced to the Council as the official representative of the British Association for the Advancement of Science at this meeting of the American Association. He had been invited to attend the council sessions and to take part in the discussions. He presented a letter of greeting from the British Association, which the secretary read to the Council. The letter follows : 'The Council of the British Association for the Advancement of Science through its representative, Professor Herbert Hall Turner, F.R.S. (lately a General Secretary of the Association) desires to convey to the American Association for the Advancement of Science an expression of its cordial good will and every hope for a most successful meeting.'—W. H. Bragg, President. The Chairman expressed to Professor Turner the pleasure of the Council in having him in attendance at this meeting, saying that the American Association was very greatly honoured by having as special delegate from its sister association a research worker of Professor Turner's eminence and a past general secretary of the British Association. Professor Turner responded by expressing his gratification at being the official representative of the British Association on this occasion, and added an interesting and valuable account of some features of the manner in which preparations are made for British Association meetings. He emphasized the excellent results obtained by bringing the section secretaries together early in the year for a day or two devoted to discussions of plans for the approaching meeting. Professor Turner emphasized the fact that these preliminary conferences of section secretaries had resulted in specially valuable joint sessions of two or more sections, in which science workers in different but related fields are brought together.

Professor Turner suggested that it might be desirable to have arrangements by which some funds might be used to encourage young workers in science to attend the Association meetings, thus bringing them into early contact with the older members. He described briefly how this is accomplished in some instances by the British Association. A brief discussion followed, and attention was called to the fact that some of the special scientific societies in America have junior or associate membership by which students may have the benefit of the meetings without paying the whole of the regular dues. This whole question was referred to the Executive Committee with the request that it consider the possibilities and report to the Council at a later session.

Professor Turner . . . presented a message from Mr. O. J. R. Howarth, Secretary of the British Association, calling attention to the exceedingly high prices charged by some European publishers of scientific periodicals, and suggesting that the American Association take this under consideration. After considerable discussion, this was referred to the Executive Committee.

The Council expressed to the British Association for the Advancement of Science its hearty appreciation of the courtesy of that Association in sending to the New York meeting a special official representative . . . and thanked Professor Turner for taking part in its deliberations and for delivering an address at one of the general sessions of this meeting.

* * *

Professor Turner gave a lecture on 'The Scientific Retrospect,' which was very well received, at one of our afternoon general sessions. He also introduced Dr. Harlow Shapley, who gave a popular lecture, on 'Galaxies outside of the Milky Way,' at the last evening session of the meeting.

I am sure that Professor Turner's visit was very productive and stimulating in many ways.

* * *

Another matter that I wish to bring to your attention is indicated by the following minute from one of the Council sessions.

'On recommendation by the Executive Committee the Council requested the Permanent Secretary to communicate with the British Association with regard to the desirability of forming a joint committee to consider the interrelations of these two organisations and their relations with other scientific associations. The Council named the President and the Permanent Secretary to represent the American Association in the proposed Committee.'

The idea of this minute was suggested by some of those who were official representatives of the American Association at the last meeting of the British Association. Professor Kennelly was particularly interested in the general thought that some arrangement might be made by which these two great English-speaking associations might operate together when occasion might arise. Our Council and Executive Committee did not give very much attention to possible details but instructed me to take this matter up with the British Association. I shall be glad to receive suggestions from you in this connection.

IV. *South African Meeting.*—Preparations for this Meeting have fully occupied the executive officers during the year. The South African Committee of the Council has held seventeen meetings. It has been charged, among other important duties, with the allocation of the funds generously furnished by the Government of the Union of South Africa and the South African Association for the Advancement of Science, supplemented by a fund raised at home through the instrumentality of Dr. F. E. Smith.

Contributors to this latter fund, whose generosity has been acknowledged by the Council, are Barclays Bank (Dominion, Colonial and Overseas), Sir Otto Beit, the Central Mining and Investment Corporation, Mr. T. B. Davis, Mr. F. Dudley Docker, Rt. Hon. Lord Glendyne, Imperial Chemical Industries, Ltd., Hon. Henry Mond, Sir John Mullens, the Standard Bank of South Africa, the Union Castle Mail Steamship Co., Ltd. The thanks of the Council have been conveyed to these generous donors.

These funds have been devoted mainly to grants in aid of travelling expenses of officers and other invited members, and a reserve has been held to assist the funds of the Association in covering expenses connected with the Meeting.

The Council received from the Rhodes Trustees the generous offer of three grants of £70 each to selected students, or junior members of staff, from home Universities, to enable them to attend the Meeting, and the Committee added thereto three equivalent grants, thus enabling the principle (though not the number) of the British Association Exhibitions awarded in recent years to be maintained.

The previous offer of the Rhodes Trustees (referred to in the last Report of the Council) to make a grant of £250 toward a further authoritative investigation of the ruins at Great Zimbabwe or a neighbouring site, was supplemented by the Council out of accumulated interest of the Caird Fund, so as to provide a total of £1,000. The Council was fortunate in securing the services of Miss Gertrude Caton-Thompson to supervise the necessary excavation, with the assistance of Miss Norie and Miss Kenyon, and desired her to report the results at the Meeting. The co-operation of the Southern Rhodesian authorities in allocating sites at Great Zimbabwe and Dhlo-Dhlo for Miss Caton-Thompson's investigation is gratefully acknowledged.

Following the Secretary's report of his consultation with the Executive in South Africa last year, the Council resolved to exercise its power, so far as its South African Committee might judge necessary, of imposing conditions in respect of membership of the visiting party. At the outset it required of new applicants for membership the recommendation of a member of the General Committee. Subsequently the visiting party increased to

a number in excess of the largest estimate originally formed, and the South African Committee found it desirable to limit late entries to practising scientific workers invited by the Committee.

V. *Association Française pour l'Avancement des Sciences*.—Following upon the cordial invitation received by the General Committee from the French Association through Dr. A. Loir, and accepted, for any members of the British Association not visiting South Africa to attend the meeting of the French Association in July, the Council appointed Sir Henry Lyons as its official representative at that meeting and as Chairman of an Organising Committee for arrangements in connection with the visit. The Conference of Delegates of Corresponding Societies was appointed to take place in Havre under the Presidency of Dr. F. A. Bather (*vice* the late Sir George Fordham), with Dr. C. Tierney as Secretary and Mr. T. Sheppard as Acting Secretary for the Meeting.

VI. *Centenary Meeting, 1931*.—The General Committee having expressed the wish that the Centenary Meeting should take place in London, the Council is happy to report the receipt of a letter, dated February 26, 1929, from the Town Clerk of the City of London, in the following terms:—

I am asked by the Court of Common Council to express the hope that London will be selected as the place for the holding of the Centenary Meeting of the British Association in 1931. In that event, the Corporation will be happy to give an Entertainment to the Association—the precise form of which can be determined later.

I may add that it is proposed to appoint a Ward Committee to carry out the arrangements decided upon.

Under the authority delegated to it by the General Committee at the Glasgow Meeting, the Council gratefully accepted this invitation, and has under consideration the venue of the inaugural and other meetings, etc., which could not be conveniently accommodated within the City boundaries.

The Council was represented by Prof. J. L. Myres, with the Secretary in attendance, at a meeting of representatives of interested societies convened by the Royal Institution to consider the celebration in 1931 of the centenary of Faraday's discovery of electro-magnetic induction, and subsequently, by invitation, appointed Dr. F. E. Smith to represent it on a Committee formed to further this object. It is desired that this celebration may immediately precede the Centenary Meeting of the British Association, and the Council feels that such an arrangement would enhance the scientific importance of both occasions.

In view of the known desire in York, the birthplace of the Association, that the Centenary Meeting should take place there, the Council gave instructions that the reasons which had led to the reluctant rejection of this proposal should be fully laid before the authorities in York. They were at the same time informed of the alternative suggestion mentioned to the General Committee at Glasgow, namely (*a*) that there should be a week-end excursion to York during the Centenary Meeting, (*b*) that the Annual Meeting in 1932 should be held in York (a course to which the authorities of Leicester present at the Glasgow Meeting gave assent, expressing their willingness to defer their own invitation to the year 1933). The authorities in York accepted the above suggestion, and with the concurrence of those in Leicester it is now confirmed that the Annual Meeting in 1932 will be held in York, and that in 1933 in Leicester.

VII. *Suggested Meeting in India*.—A suggestion was received as to the possibility of a meeting of the Association in India, but the Council felt that on the score of season and climate any proposal to hold an ordinary meeting there could not be encouraged. The Council however suggested, on its part, that the Indian Science Congress or other suitable authority might invite the British Association to send a scientific deputation to a joint meeting.

VIII. *Down House*.—Thanks to the generosity of Mr. G. Buckston Browne, the Association now possesses, in custody for the nation, Down House, where Darwin thought and worked for forty years, and died in 1882. Mr. Buckston Browne, besides vesting in the Association the sum of £20,000 for the maintenance of the property, has fully restored the house (an extensive and urgent work), and has placed the ground floor in a condition appropriate to exhibition to the public; in particular, the Old Study, where the *Origin of Species* was written, has been brought as nearly as possible to an exact replica of its condition in Darwin's time, with much of the original furnishing and copies of, or close approximations to, the rest. Under Mr. Buckston Browne's inspiration, members of Darwin's family, and others, have liberally given original furniture and other objects of interest for preservation in the house. The restoration of the gardens and the Sand Walk is also in progress. Thanks again to Mr. Buckston Browne, the house is adequately staffed. The Council desired the Secretary, Mr. Howarth, to occupy the residential portion of the house as resident officer, for a period of not less than five years, and he will do so. Full consideration will be given to the possibility of applying the estate to some direct scientific purpose.

The personnel of the Down House Committee appointed by the General Committee on September 5, 1928, was completed by the nomination of Sir Arthur Keith as representative of the Royal College of Surgeons.

The Council learned with pleasure that the American Association for the Advancement of Science, at the instance of Prof. H. Fairfield Osborn, has appointed a Committee to co-operate with the Association for the benefit of the estate: an important collection of letters from Darwin to Fritz Muller has already been secured from South America through this generous agency.

With a view to the exemption from rates of premises held for 'charitable' purposes, the Association has been registered by the Registrar of Friendly Societies as entitled to the benefit of the Scientific Societies Act, 1843.

Down House was formally dedicated to the public access on June 7 at a meeting attended by many members of the General Committee, representatives of Darwin's family, scientific societies with which Darwin was connected, and other invited guests. Dr. Joseph Leidy represented the American Association for the Advancement of Science and the Philadelphia Academy of Natural Sciences, and has generously presented to Down House the bust of Darwin exhibited by Mr. C. L. Hartwell in this year's Royal Academy. Prof. E. B. Poulton represented Prof. H. F. Osborn and the American Museum of Natural History, Prof. R. Anthony represented French science, and Prof. Abe the Japanese Darwin Society. The American Ambassador also was represented.

At this meeting, the desire was expressed to nominate Mr. Buckston Browne as Hon. Curator of Down House, and this proposal was received with acclamation.

IX. *Income Tax*.—The Council reported last year that the cases taken as test cases upon the liability of scientific Societies to taxation of income had been decided against the Societies by the Special Commissioners and the High Court; to these were subsequently added the Court of Appeal, and the question was not carried to the House of Lords. The position is that the two societies concerned, the Geologists' Association and the Midland Counties Institution of Engineers, were adjudged on the facts, as found by the Special Commissioners, not to be 'charities' exempted from taxation under the Income Tax Act, 1918.

The Council caused a further meeting of representatives of affected Societies to be summoned, when the following principal considerations emerged :—

(1) No satisfactory definition of a 'charity' applicable to scientific societies generally has been found. The cases referred to above were brought as test cases: the judgments show that they do not provide a common 'test' and indicate that no individual case can indeed act as such.

(2) It has been laid down by the judicature that :—

(a) If a society exists mainly for the purpose of furthering science and incidentally its own members benefit, such society is entitled to exemption.

(b) If a society exists mainly to benefit its members individually (as in the case of conferring professional prestige), while incidentally furthering science, such society is not entitled to exemption.

(3) Some societies definitely fall on the side of non-liability, some on that of liability: as to a third category, it is arguable on which side they should fall.

(4) Therefore the case of each society must be separately investigated.

(5) But in the mutual interest of societies, the meeting recommended community of action in order to ensure a pooling of experience, and to that end the officers of the British Association offered :—

(a) To advise societies (so far as lies in their power) as to procedure, and

(b) To file in the office of the Association records of the results of individual societies' appeals and of the grounds of their success or failure, in order that such records may be available for consultation and general guidance.

It became clear that the above statements (3) and (4) correctly represented the position from the fact that the Association itself, and certain other societies, since the judicial decisions referred to, have been allowed remission of tax as heretofore, on a review of their activities by the Inland Revenue authorities. Others have not, and consideration of individual cases is understood to be in progress.

The expert assistance of the General Treasurer in this important matter has been deeply appreciated.

X. *Resolutions* referred by the General Committee at the Glasgow Meeting to the Council for consideration, and, if desirable, for action, were dealt with as follows :—

(a) Resolutions from Section E (Geography), relating to the completion of the thirtieth meridian arc in East Africa, the uniform map of Africa (Geographical Section, General Staff, 1: 2,000,000), and the periodical revision of the Ordnance Survey, were referred, with commentaries, to the appropriate Government Departments (Colonial Office, War Office, Ministry of Agriculture and Fisheries).

In regard to the first, it is understood that Col. H. St. J.

Winterbotham, in the course of a tour through the British Empire for the purpose of advising the various Governments on survey matters, will pay special attention to the question of this meridian arc.

In regard to the publication of the uniform map of Africa, the Army Council agreed with the principle of the resolution, and a full statement kindly furnished by the Colonial Office and that Council shows that in regard to a large part of Africa the objects indicated by the resolution are in process of realisation.

The revision of the Ordnance Survey is understood to receive constant attention subject to the limits imposed by financial considerations.

(b) On the question of the high cost of foreign scientific publications, the Council was represented at a meeting of the Library Committee of the Royal Society dealing with this matter, and also brought it, through Prof. H. H. Turner (§ III), to the attention of the American Association for the Advancement of Science. (Resolution of Section H, Anthropology.)

(c) The Council is in correspondence with Australian authorities on the question of the study of Australian aboriginal languages. It has received from the Canadian authorities a sympathetic reply on the question of publishing results of field work of the Anthropological Division of the Geological Survey of Canada. (Resolutions of Section H, Anthropology.)

(d) The Council resolved against action upon the resolution relating to key industries duty upon scientific apparatus for use in educational laboratories. (Resolution of Section J, Psychology.)

(e) On the question of increased research and expenditure upon the preservation of timber, the Council resolved to make no recommendation, while willing to forward specific suggestions for researches to the proper quarters. (Resolution of Section K, Botany.)

(f) In regard to the recommendation that past Recorders should be ex-officio members of Organising Sectional Committees, the Council considers the existing opportunity to include these ex-officers, if desired, by appointment is sufficient. (Resolution of Section L, Educational Science.)

(g) The resolution referring to the preservation of scenic amenity in town and country was forwarded to H.M. Secretary of State for Home Affairs, together with the address by Dr. Vaughan Cornish and the report of the discussion which gave rise to the resolution. (Resolution of the Conference of Delegates of Corresponding Societies.)

XI. *General Treasurer's Account.*—The Council has received reports from the General Treasurer throughout the year. With the knowledge that his account for the year ending June 30, 1929, could not be prepared in time for presentation to the General Committee at the South African Meeting, the Committee has already delegated to the Council the power to receive and deal with the account, in November next.

The Council made grants of £100 each from the income of the Caird Fund to the Naples Table Committee and the Seismology Committee. Accumulated interest on the fund was allocated toward the cost of the excavations at Great Zimbabwe, etc. (§ IV).

XII. General Officers.—The General Officers have been nominated by the Council as follows :—

General Treasurer, Sir Josiah Stamp.

General Secretaries, Prof. J. L. Myres and Dr. F. E. Smith.

XIII. Council Membership.—The retiring Ordinary Members of the Council are :—Lord Bledisloe, Prof. E. G. Coker, Dr. H. H. Dale, Mr. C. T. Heycock, Dr. C. S. Myers.

The Council nominates the following new members :—Sir Daniel Hall, Sir James Henderson, Prof. J. F. Thorpe ; leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows :—

Prof. J. H. Ashworth.
Dr. F. A. Bather.
Prof. A. L. Bowley.
Prof. C. Burt.
Prof. W. Dalby.
Prof. C. Lovatt Evans.
Sir John Flett.
Sir Henry Fowler.
Sir Richard Gregory.
Prof. Dame Helen Gwynne-Vaughan.
Sir Daniel Hall.
Sir James Henderson.

Mr. A. R. Hinks.
Sir Henry Lyons.
Mr. C. G. T. Morison.
Prof. T. P. Nunn.
Prof. A. O. Rankine.
Mr. C. Tate Regan.
Prof. A. C. Seward.
Dr. F. C. Shrubbsall.
Dr. N. V. Sidgwick.
Dr. G. C. Simpson.
Prof. J. F. Thorpe.

XIV. General Committee Membership.—Mr. F. Puryer White has been admitted as a member of the General Committee.

XV. Corresponding Societies Committee.—The Corresponding Societies Committee has been nominated as follows : The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), The General Treasurer, the General Secretaries, Mr. C. O. Bartrum, Dr. F. A. Bather, Sir Richard Gregory, Sir David Prain, Sir John Russell, Prof. W. M. Tattersall.

XVI. Honorary Members.—The Council has received the thanks of the Hon. Sir Charles Parsons, Sir Alfred Yarrow, and Mr. G. Buckston Browne for their election to honorary membership of the Association by the General Committee.

RESOLUTIONS & RECOMMENDATIONS.

The following resolutions and recommendations were referred to the Council by the General Committee at Johannesburg for consideration and, if desirable, for action :—

From Section A.

To urge the importance of the establishment, on a suitable site in South Africa, of an observatory for the study of terrestrial magnetism and atmospheric electricity.

The establishment of such an observatory would add very greatly to the accuracy and value of the magnetic survey of South Africa which is now in progress. The Committee desires to call attention, moreover, to the fact that at present there is only one magnetic observatory, viz. at Helwan, Egypt, and regular observations in South Africa are much needed for the study of the Earth's magnetism.

From Section C (supported by Section H).

That the British Association for the Advancement of Science strongly support the South African Association for the Advancement of Science in its endeavours to preserve Nooitgedacht Farm, near Riverton, as a national monument. The glacially striated pavements there, with their rock carvings, are of such interest and importance that every effort should be made to preserve them.

From Section D.

That the Section is strongly of opinion that some system of temporary exchange between the staffs of the Government museums throughout the Empire would be in the public interest, and urges the Council to press the matter with the appropriate authorities. Alternatively, a system of 'study leave' similar to that in force in India is suggested.

From Section D.

That the Section considers that it is of the greatest importance that an international biological and oceanographical station should be established in the Malay Archipelago, and urges the Council to support the Fourth Pan-Pacific Science Congress by every means in its power to make their efforts in this matter effective.

From Section D.

That the Section is of opinion that it is very desirable that more adequate facilities should be available for marine biological investigation in South Africa, especially in the form of more marine laboratory accommodation; and recommends that the matter should receive the careful attention of the appropriate authorities.

From Section E.

To recommend that the British Association represent to the South African Government the need, when sufficient funds are available, for expediting the topographical survey of South Africa, the completion of which appears to be urgently required for all scientific and educational purposes.

From Section H.

In the Committee of Section H it was resolved to ask the Council of the Association to represent to the Federal Government of Australia the urgent need for more effective measures, before it is too late, to protect the aborigines of Australia and prevent their extinction. Apart from humanitarian considerations, the Australian natives are among the most interesting and the most valuable peoples for scientific study, and, if they are allowed to die out, Science will lose material that may be of unique importance for future investigations in the early history of mankind.

From Section H.

To call attention to the destruction of monuments, objects and sites in South Africa, of anthropological, archæological and other interest, which are of permanent national value; and to ask the Council to consider, in conjunction with public bodies and scientific societies in South Africa, what provision may best be made for their preservation.

From Section H.

The Sectional Committee asks that a report of Miss Caton-Thompson's paper appear in the Annual Report, and that the Council be desired to consider the full publication of her results as a monograph.

BRITISH ASSOCIATION FOR THE ADVANCEMENT
OF SCIENCE.

GENERAL TREASURER'S ACCOUNT

JULY 1, 1928, TO JUNE 30, 1929.

Note.—Owing to the early date of the South African Meeting, the General Committee authorised the Council to receive and adopt these accounts, which could not be presented at the meeting itself.

The large apparent increase in cost of printing is due in part to the special requirements of the South African Meeting, but also to the early date of that meeting, which brought into the current year expenditure which normally would fall in the year following.

The absence of Prof. A. W. Kirkaldy's signature as Hon. Auditor was due to indisposition, of which the Council learned with great regret.

Balance Sheet,

Corresponding Figures June 30, 1928.			LIABILITIES.			£ s. d.			£ s. d.		
£	s.	d.									
			To General Fund—								
			As at July 1, 1928			10,692 19 1					
			Add Prof. A. W. Scott's Legacy as at July 1, 1928			250 0 0					
10,692	19	1	As per contra						10,942	19	1
			(Subject to Depreciation in Value of Investments)								
			„ Caird Fund—								
			As per contra						9,582	16	3
9,582	16	3	(Subject to Depreciation in Value of Investments)								
			„ Caird Fund Revenue Account—								
			Balance at July 1, 1928			715 1 6					
			Less Excess of Expenditure over Income for the year			513 17 8					
715	1	6	As per contra						201	3	10
			„ Sir F. Bramwell's Gift for Enquiry into Prime Movers, 1931—								
			£50 Consols now accumulated to £151 12s.								
			As per contra						76	7	3
72	13	8	„ Sir Charles Parsons' Gift—as per contra						10,000	0	0
10,000	0	0	„ Sir Alfred Yarrow's Gift—								
			As per last Account			9,700 0 0					
			Less Transferred to Income and Expenditure Account under the terms of the Gift			310 17 9					
9,700	0	0	As per contra						9,389	2	3
			„ Life Compositions—								
			As per last Account			1,308 12 2					
			Add Received during year			330 0 0					
1,308	12	2	As per contra						1,638	12	2
			„ Toronto University Presentation Fund—								
			As per last Account			182 18 10					
			Add Dividends			8 15 0					

June 30, 1929.

Corresponding

Figures
June 30,
1928.

£ s. d.

ASSETS.

£ s. d.

£ s. d.

By *Investments on Capital Accounts—**General Fund—*

£4,651 10s. 5d.	Consolidated 2½ per cent. Stock at cost	3,942 3 3	
£3,600	India 3 per cent. Stock at cost	3,522 2 6	
£879 14s. 9d.	£43 Great Indian Peninsula Railway 'B' Annuity at cost	827 15 0	
£52 12s. 7d.	War Stock (Post Office Issue) at cost	54 5 2	
£834 16s. 6d.	4½ per cent. Conversion Loan at cost	835 12 4	
£1,400	War Stock 5 per cent. 1929/47 at cost	1,393 16 11	
£94 7s. 4½ per cent.	Conversion Stock 1940/44 at cost	62 15 0	
£326 9s. 10d.	3½ per cent. Conversion Stock at cost	250 0 0	
	Cash at Bank	54 8 11	

10,692 19 1

10,942 19 1

(Value of Stocks at date, £8,134 2s. 3d.)

Caird Fund—

£2,627 0s. 10d.	India 3½ per cent. Stock at cost	2,400 13 3	
£2,100	London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock at cost	2,190 4 3	
£2,500	Canada 3½ per cent. 1930/50 Registered Stock at cost	2,397 1 6	
£2,000	Southern Railway Consolidated 5 per cent. Preference Stock at cost	2,594 17 3	

9,582 16 2

9,582 16 3

(Value at date, £6,878 4s. 3d.)

Caird Fund Revenue Account—

Cash at Bank 201 3 10

715 1 6

Sir F. Bramwell's Gift—

£145 1 3	Self-Accumulating Consolidated Stock as per last Balance Sheet	72 13 8	
6 10 9	Add Accumulations to June 30, 1929	3 13 7	
£151 12 0			

72 13 8

76 7 3

(Value at date, £82 12s. 5d.)

Sir Charles Parsons' Gift—

£10,300 4½ per cent. Conversion Loan 10,000 0 0

10,000 0 0

£10,145 10s. (Value at date, £9,733 10s.)

Sir Alfred Yarrow's Gift—

£9,700 5 per cent. War Loan (£50 Bonds) 1929/47 as per last Balance Sheet 9,700 0 0

9,700 0 0

Less Sale of £310 17s. 9d. Stock under terms of the Gift 310 17 9

(Value at date, £9,459 10s. 6d.)

9,389 2 3

Life Compositions—

£2,361 7s. 8d. Local Loans at cost 1,533 12 2

(Value at date, £1,464 1s. 1d.)

Cash at Bank 105 0 0

1,308 12 2

1,638 12 2

Toronto University Presentation Fund—

£175 5 per cent. War Stock at cost 178 11 4

£177 16s. 11d. (Value at date, £176 6s. 3d.)

Cash at Bank 4 7 6

182 18 10

182 18 10

Prof. A. W. Scott's Legacy—

£326 9s. 10d. 3½ per cent. Conversion Stock

250 0 0

South Africa Meeting Fund—

Cash at Bank 1,728 9 3

—

*Mr. G. Buckston Browne's Gift in Memory of Darwin, Down House, Kent (not valued)—**Do. Endowment Fund—*

£5,500 India 4½ per cent. Stock 1958/68 at cost 5,001 17 4

£2,500 Australia 5 per cent. Stock 1945/75 at cost 2,468 19 0

£3,000 Fishguard & Rosslare Railway 3½ per cent. Guaranteed Preference Stock at cost 2,139 17 3

£2,500 New South Wales 5 per cent. 1915/65 Stock at cost 2,467 7 9

£2,500 Western Australia 5 per cent. Stock 1945/75 at cost 2,472 1 6

£3,340 Great Western Railway 5 per cent. Guaranteed Stock at cost 3,436 7 5

£2,500 Birkenhead Railway 4 per cent. Consolidated Stock at cost 2,013 9 9

(Value at date, £19,247 6s.)

20,000 0 0

Royal Charter Expenses—

Cash at Bank

47 19 3

42,553 0 9

Carried forward £63,742 8 11

Balance Sheet.

Corresponding
Figures,
June 30,
1928.

LIABILITIES—continued.

Brought forward	£ 72,135	s. 13	d. 5
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49,032 15 9

£72,135 13 5

I have examined the foregoing Accounts with the Books and Vouchers and certify the same inspected the Deeds of Down House and the Mortgage on Isleworth House.

Approved.

ARTHUR L. BOWLEY.

Auditor.

November 1929.

Down House,

EXPENDITURE.

	£	s.	d.	£	s.	d.
To Wages of Gardeners				126	0	6
„ Rates, Insurance, etc.				12	9	3
„ Heat, Light and Drainage				111	3	9
„ Repairs, Renewals and Alterations to Buildings, Fences, Paths, etc.				277	6	7
„ House and Garden Equipments				183	15	5
„ Sundry Expenses	11	1	5			
„ Photographs	11	2	3			
„ Printing Booklet	92	7	6			
				114	11	2
„ Law Costs—						
Collection of Rents	3	8	9			
Surrender of Lease	14	14	0			
				18	2	9
„ Opening Ceremony—						
Catering and Conveyance				192	0	6
				£1,035	9	11

June 30, 1929—*continued.*Corresponding
Figures,
June 30,
1928.£ s. d.
42,553 0 9ASSETS—*continued.*

	£	s.	d.	£	s.	d.
Brought forward				63,742	8	11
By Revenue Account—						
£2,093 1s. 9d. Consolidated 2½ per cent. Stock at cost	1,200	0	0			
£4,338 6s. 2d. Conversion 3½ per cent. Stock at cost	3,300	0	0			
£400 5 per cent. War Loan Inscribed Stock at cost	404	16	0			
£1,970 14s. 8d. Value at date, £4,854 8s. 4d.						
Second Mortgage on Isleworth House, Orpington	700	0	0			
Down House Suspense Account—						
Compensation paid to Outgoing Tenant	£800	0	0			
Redemption of Tithe	138	7	0			
	938	7	0			
Do. Excess of Expenditure for Upkeep over Income for the period as per separate Income and Expenditure Account	699	13	7			
Sundry Debtors and Payments in Advance	410	5	10			
Do. (Down House)	172	3	4			
Cash at Bank—General Account £1,739 4 0						
Less Down House overdraft	1,184	6	10			
	554	17	2			
Cash in Hand	13	1	7			
				8,393	4	6
				£72,135	13	5

6,479 15 0

49,032 15 9

to be correct. I have also verified the Balances at the Bankers and the Investments, and have

W. B. KEEN,
Chartered Accountant.

June 30, 1929.

INCOME.

	£	s.	d.	£	s.	d.
By Rents Receivable				115	8	4
„ Dividends—						
4½ per cent. India Stock	61	12	0			
Fishguard and Rosslare Railway	42	0	0			
New South Wales Stock	50	0	0			
Great Western Railway Stock	66	16	0			
				220	8	0
„ Balance, being excess of Expenditure over Income				699	13	7

£1,035 9 11

Income and
FOR THE YEAR ENDED

Corresponding
Period
June 30,
1928.

EXPENDITURE.

£	s.	d.		£	s.	d.	£	s.	d.
24	2	1	To Heat, Lighting and Power	26	13	7			
58	16	3	„ Stationery	94	0	10			
1	0	0	„ Rent	1	0	0			
191	12	0	„ Postages	201	14	6			
165	19	1	„ Travelling Expenses	438	11	9			
91	13	8	„ Exhibitioners	70	19	11			
212	3	11	„ General Expenses	286	4	6			
745	7	0		1,119	5	1			
1,335	9	0	„ Salaries and Wages	1,439	9	3			
75	0	0	„ Pension Contribution	75	0	0			
1,385	16	11	„ Printing, Binding, etc.	2,882	0	3	5,515	14	7
3,541	12	11	„ The Secretary's Travelling Expenses to South Africa, recoverable per contra						
145	2	2	„ Dr. Klercker's Research Donation per contra				25	0	0
22	0	0	„ Prof. T. T. Barnard for Excavations at Bambata				80	0	0
			„ Miss Caton-Thompson for Zimbabwe Excavations per contra				250	0	0
			„ Grants to Research Committees—						
			Trent Committee	20	0	0			
			Pigment in Insecta Committee	6	0	0			
			Sumerians Committee	100	0	0			
			School Certificate Committee	12	2	1			
			Transplant Committee	35	0	0			
			Sex Ratio Committee	10	0	0			
			Macedonia Committee	50	0	0			
			Quaternary Peats Committee	10	0	0			
			British Flora Committee	50	0	0			
			Tables of Constants Committee	5	0	0			
			African Lakes Committee	50	0	0			
			Bronze Implements Committee	50	0	0			
			Plymouth Table Committee	50	0	0			
			Taxation Committee	25	0	0			
			Zoological Record Committee	50	0	0			
			Great Barrier Reef Committee	200	0	0			
			Ductless Glands Committee	30	0	0			
			Overseas Training Committee	10	0	0			
			Palæozoic Rocks Committee	25	0	0			
			Vocational Tests Committee	50	0	0			
			Population Map of the British Isles Committee	50	0	0	888	2	1
476	5	1	„ Law Costs of Second Mortgage Isleworth House				24	10	2
1,049	1	0	„ Balance, being excess of Income over Expenditure for the year						
5,234	1	2					£6,783	6	10

Caird

EXPENDITURE.

£	s.	d.		£	s.	d.	£	s.	d.
100	0	0	To Grants Paid—						
100	0	0	Seismology Committee	100	0	0			
			Naples Tables Committee	50	0	0			
			Zimbabwe Excavations	750	0	0			
			Notes and Queries on Anthropology (5th Edition	50	0	0	950	0	0
10	10	0	Technical Education Committee						
80	5	0	„ Balance being Excess of Income over Expenditure for the year						
290	15	0					£950	0	0

Expenditure Account

JUNE 30, 1929.

Corresponding Period June 30, 1928.		INCOME.			
£ s. d.		£ s. d.		£ s. d.	
185 10 0	By Annual Regular Members (Including £61, 1929/30, and £1, 1930/31)			185 0 0	
1,508 5 0	.. Annual Temporary Members (Including £408, 1929/30, and £1, 1930/31)			1,944 0 0	
523 10 0	.. Annual Members with Report (Including £190 10s., 1929/30)			834 0 0	
108 15 0	.. Transferable Tickets			71 5 0	
131 0 0	.. Students' Tickets (Including £5 10s. for 1929/30) (Total Tickets as above, issued in advance for 1929/30 South African Meeting, £665)			91 10 0	
	.. The Secretary's Travelling Expenses to South Africa, recoverable from the South African Association per contra			—	
145 2 2	.. Donation—Dr. Klercker, per contra			25 0 0	
22 0 0	.. Donation (Fcs. 10,000) per L'Abbé Breuil, for Excavations at Bambata			80 9 3	
	.. Donation—Rhodes Trustees for Zimbabwe Excavations, per contra			250 0 0	
5 0 0	.. Lift Rent			5 0 0	
47 7 6	.. Interest on Deposits			104 5 6	
705 17 6	.. Sale of Publications			568 4 1	
223 15 3	.. Advertisement Revenue			241 2 9	
	.. Income Tax recovered—				
	Year 1926-27	298 18 7			
	Year 1927-28	303 1 11			
				602 0 6	
8 13 5	.. Unexpended Balance of Grants returned			37 16 11	
22 10 0	.. Liverpool Exhibitioners			22 10 0	
	.. Royal Charter Expenses—				
	Unexpended Balance transferred			29 11 11	
	.. Dividends—				
£135 0 0	Consols	135 0 0			
36 8 0	India 3 per cent. Stock	86 8 0			
26 13 3	Great Indian Peninsula Rly. 'B' Annuity	26 15 2			
30 1 2	4½ per cent. Conversion Loan	34 6 0			
370 16 0	Ditto, Sir Charles Parsons' Gift	370 16 0			
53 11 10	Local Loans	53 6 6			
68 12 6	War Stock	78 12 6			
338 0 0	Ditto, Series 'A,' Sir A. Yarrow's Gift	428 14 6			
130 12 4	3½ per cent. Conversion Loan	130 12 4			
1,289 15 1				1,344 11 0	
	By Sir Alfred Yarrow's Gift—				
	Proceeds of Sale of £310 17s. 9d. War Loan, in accordance with terms of the Gift	310 17 9			
307 0 3	Profit on Sale	4 2 3			
				315 0 0	
	.. Interest on Mortgage			16 8 10	
—	.. Balance, being excess of Expenditure over Income for the year			15 11 1	
5,234 1 2				£6,783 6 10	

Fund.

£ s. d.		INCOME.			
£ s. d.		£ s. d.		£ s. d.	
	By Dividends—				
	India 3½ per cent. Stock	73 11 0			
	Canada 3½ per cent. Stock	70 0 0			
	London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock	67 4 0			
	Southern Railway Consolidated 5 per cent. Preference Stock	80 0 0			
290 15 0				290 15 0	
	By Income Tax recovered—				
	Year 1926-27	72 13 8			
	Year 1927-28	72 13 8			
				145 7 4	
—	.. Balance, being excess of Expenditure over Income for the year			513 17 8	
£290 15 0				£950 0 0	

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN
SOUTH AFRICA, 1929.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological Investigations.—Prof. H. H. Turner (*Chairman*), Mr. J. J. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. J. E. Crombie, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Dr. H. Jeffreys, Prof. H. Lamb, Sir J. Larmor, Prof. A. E. H. Love, Prof. H. M. Macdonald, Dr. A. Crichton Mitchell, Mr. R. D. Oldham, Prof. H. C. Plummer, Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, Sir A. Schuster, Sir Napier Shaw, Sir G. T. Walker, Dr. F. J. W. Whipple. **£100** (Caird Fund grant).

Tides.—Prof. H. Lamb (*Chairman*), Dr. A. T. Doodson (*Secretary*), Dr. G. R. Goldsbrough, Dr. H. Jeffreys, Prof. J. Proudman, Prof. G. I. Taylor, Prof. D'Arcy W. Thompson, Commander H. D. Warburg.

Annual Tables of Constants and Numerical Data, chemical, physical, and technological.—Sir E. Rutherford (*Chairman*), Prof. A. W. Porter (*Secretary*), Mr. Alfred Egerton. **£5.**

Calculation of Mathematical Tables.—Prof. J. W. Nicholson (*Chairman*), Prof. A. Lodge (*Vice-chairman*), Dr. L. J. Comrie (*Secretary*), Dr. R. A. Fisher (*General Editor*), Dr. J. R. Airey, Dr. A. T. Doodson, Dr. J. Henderson, Mr. J. O. Irwin, Prof. A. E. H. Love, Prof. E. H. Neville, Dr. A. J. Thompson, Dr. J. E. Tocher, Mr. T. Whitwell, Dr. J. Wishart, Dr. Dorothy Wrinch. **£30.**

SECTION B.—CHEMISTRY.

To consider the possibilities of publishing a compilation of recent material on the subject of Colloid Chemistry.—Prof. F. G. Donnan (*Chairman*), Dr. W. Clayton (*Secretary*), Mr. E. Hatschek, Prof. W. C. McC. Lewis, Dr. E. K. Rideal, Sir R. Robertson.

Absorption Spectra and Chemical Constitution of Organic Compounds.—Prof. I. M. Heilbron (*Chairman*), Prof. E. C. C. Baly (*Secretary*), Prof. A. W. Stewart.

SECTION C.—GEOLOGY.

To excavate Critical Sections in the Palæozoic Rocks of England and Wales.—Prof. W. W. Watts (*Chairman*), Prof. W. G. Fearnside (*Secretary*), Mr. W. S. Bisat, Dr. H. Bolton, Prof. W. S. Boulton, Mr. E. S. Cobbold, Prof. A. H. Cox, Mr. E. E. L. Dixon, Dr. Gertrude Elles, Prof. E. J. Garwood, Prof. H. L. Hawkins, Prof. V. C. Illing, Prof. O. T. Jones, Prof. J. E. Marr, Dr. F. J. North, Mr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, Dr. A. E. Trueman, Dr. F. S. Wallis. **£25.**

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. C. V. Crook, Mr. A. S. Reid, Prof. W. W. Watts, Mr. R. I. Welch.

To investigate Critical Sections in the Tertiary Rocks of the London Area. To tabulate and preserve records of new excavations in that area.—Prof. W. T. Gordon (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Miss M. C. Crosfield, Prof. H. L. Hawkins, Prof. G. Hickling. **£10.**

To consider the opening up of Critical Sections in the Mesozoic Rocks of Yorkshire.—Prof. P. F. Kendall (*Chairman*), Mr. M. Odling (*Secretary*), Prof. H. L. Hawkins, Dr. Spath, Mr. J. W. Stather, Mr. H. C. Versey.

To assemble information regarding the Distribution of Cleavage in North and Central Wales.—Prof. W. G. Fearnside (*Chairman*), Prof. P. G. H. Boswell and Mr. W. H. Wilcockson (*Secretaries*), Prof. A. H. Cox, Mr. I. S. Double, Dr. Gertrude Elles, Prof. O. T. Jones, Dr. E. Greenly, Mr. W. B. R. King, Prof. W. J. Pugh, Dr. Bernard Smith, Dr. A. K. Wells, Dr. L. J. Wills.

SECTIONS C, D, E, K.—GEOLOGY, ZOOLOGY, GEOGRAPHY, BOTANY.

To organise an expedition to investigate the Biology, Geology, and Geography of the Australian Great Barrier Reef.—Rt. Hon. Sir M. Nathan (*Chairman*), Prof. J. Stanley Gardiner and Mr. F. A. Potts (*Secretaries*), Sir Edgeworth David, Prof. W. T. Gordon, Prof. A. C. Seward, and Dr. Herbert H. Thomas (*from Section C*); Mr. E. Heron-Allen, Dr. E. J. Allen, Prof. J. H. Ashworth, Dr. G. P. Bidder, Dr. W. T. Calman, Sir Sidney Harmer, Dr. C. M. Yonge (*from Section D*); Dr. R. N. Rudmose Brown, Sir G. Lenox Conyngham, Mr. F. Debenham, Admiral Douglas, Mr. A. R. Hinks (*from Section E*); Prof. F. E. Fritsch, Dr. Margery Knight, Prof. A. C. Seward (*from Section K*).

SECTION D.—ZOOLOGY.

To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. E. S. Goodrich (*Chairman*), Prof. J. H. Ashworth (*Secretary*), Dr. G. P. Bidder, Prof. F. O. Bower, Prof. Munro Fox, Sir W. B. Hardy, Sir Sidney Harmer, Prof. E. W. MacBride. **£100** (Caird Fund grant).

Zoological Bibliography and Publication.—Prof. E. B. Poulton (*Chairman*), Dr. F. A. Bather (*Secretary*), Mr. E. Heron-Allen, Dr. W. T. Calman, Sir P. Chalmers Mitchell, Mr. W. L. Slater.

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth (*Chairman and Secretary*), Prof. H. Graham Cannon, Prof. J. Stanley Gardiner, Prof. S. J. Hickson. **£50**.

To co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir Sidney Harmer (*Chairman*), Dr. W. T. Calman (*Secretary*), Prof. E. S. Goodrich, Prof. D. M. S. Watson. **£50**.

On the Influence of the Sex Physiology of the Parents on the Sex-Ratio of the Offspring.—Prof. J. H. Orton (*Chairman*), Mrs. Bisbee (*Secretary*), Prof. Carr-Saunders, Miss E. C. Herdman. **£10**.

Investigations on Pigment in the Insecta.—Prof. W. Garstang (*Chairman*), Prof. J. W. Heslop Harrison (*Secretary*), Prof. A. D. Peacock, Prof. E. B. Poulton.

To consider the position of Animal Biology in the School Curriculum and matters relating thereto.—Prof. R. D. Laurie (*Chairman and Secretary*), Mr. H. W. Ballance, Dr. Kathleen E. Carpenter, Mr. O. H. Latter, Prof. E. W. MacBride, Miss M. McNicol, Miss A. J. Prothero, Prof. W. M. Tattersall.

A Preliminary Survey of Certain Tropical Lakes in Kenya in 1929.—Prof. J. Stanley Gardiner (*Chairman*), Miss P. M. Jenkin (*Secretary*), Dr. W. T. Calman, Prof. J. Graham Kerr, Mr. J. T. Saunders.

SECTIONS D, I, K.—ZOOLOGY, PHYSIOLOGY, BOTANY.

Nomenclature of Cell Structures.—Prof. C. Lovatt Evans (*Chairman*), Prof. H. E. Roaf (*Secretary*) (for Section I), Dr. J. B. Gatenby, Mr. L. A. Harvey (for Section D), Dr. K. B. Blackburn, Dr. Margery Knight (for Section K).

SECTION E.—GEOGRAPHY.

To report further as to the method of construction and reproduction of a Population Map of the British Isles with a view to the census of 1931.—Mr. H. O. Beckett (*Chairman*), Mr. A. G. Ogilvie (*Vice-Chairman*), Mr. J. Cossar (*Secretary*), Mr. J. Bartholomew, Mr. F. Debenham, Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. R. H. Kinvig, Prof. O. H. T. Rishbeth, Prof. P. M. Roxby, Mr. A. Stevens, Col. H. S. L. Winterbotham. **£75**.

To inquire into the present state of knowledge of the Human Geography of Tropical Africa, and to make recommendations for furtherance and development.—Prof. P. M. Roxby (*Chairman*), Mr. A. G. Ogilvie (*Secretary*), Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. J. McFarlane, Mr. R. U. Sayce, Col. H. S. L. Winterbotham. **£50.**

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To report on the present position of Geographical Teaching in Schools and of Geography in the training of teachers; to formulate suggestions for a syllabus for the teaching of geography both to Matriculation Standard and in Advanced Courses and to report, as occasion arises, to Council through the Organising Committee of Section E upon the practical working of Regulations issued by the Board of Education (including Scotland) affecting the position of Geography in Schools and Training Colleges.—Prof. T. P. Nunn (*Chairman*), Mr. L. Brooks (*Secretary*), Mr. A. B. Archer, Mr. C. C. Carter, Mr. J. Cossar, Prof. H. J. Fleure, Mr. O. J. R. Howarth, Mr. H. E. M. Icely, Mr. J. McFarlane, Rt. Hon. Sir Halford J. Mackinder, Prof. J. L. Myres, Dr. Marion Newbigin, Mr. A. G. Ogilvie, Mr. A. Stevens (*from Section E*); Mr. C. E. Browne, Sir R. Gregory, Mr. E. R. Thomas, Miss O. Wright (*from Section L*). **£5.**

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

To investigate certain aspects of Taxation in relation to the Distribution of Wealth.—Sir Josiah Stamp (*Chairman*), Mr. R. B. Forrester (*Secretary*), Prof. E. Cannan, Prof. H. Clay, Mr. W. H. Coates, Miss L. Grier, Prof. H. M. Hallsworth, Prof. D. H. Macgregor, Prof. J. G. Smith, Mr. J. Wedgwood, Sir A. Yarrow. **£30.**

SECTION G.—ENGINEERING.

Earth Pressures.—Mr. F. E. Wentworth-Sheilds (*Chairman*), Dr. J. S. Owens (*Secretary*), Prof. A. Barr, Prof. G. Cook, Mr. T. E. N. Fargher, Prof. A. R. Fulton, Prof. F. C. Lea, Prof. R. V. Southwell, Dr. R. E. Stradling, Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson. (Unexpended balance.)

Electrical Terms and Definitions.—Prof. Sir J. B. Henderson (*Chairman*), Prof. F. G. Baily and Prof. G. W. O. Howe (*Secretaries*), Prof. W. Cramp, Dr. W. H. Eccles, Prof. C. L. Fortescue, Prof. E. W. Marchant, Dr. F. E. Smith, Prof. L. R. Wilberforce, with Dr. A. Russell and Mr. C. C. Wharton.

Stresses in overstrained materials.—Sir Henry Fowler (*Chairman*), Mr. J. G. Docherty (*Secretary*), Prof. G. Cook, Prof. B. P. Haigh, Mr. J. S. Wilson. **£5.**

SECTION H.—ANTHROPOLOGY.

To report on the Distribution of Bronze Age Implements.—Prof. J. L. Myres (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. A. Leslie Armstrong, Mr. H. Balfour, Prof. T. H. Bryce, Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox, Mr. G. A. Garfitt.

To conduct Explorations with the object of ascertaining the Age of Stone Circles.—Mr. H. J. E. Peake (*Chairman*), Mr. H. Balfour (*Secretary*), Dr. G. A. Auden, Mr. O. G. S. Crawford, Dr. J. G. Garson, Sir Arthur Evans, Prof. J. L. Myres.

To excavate Early Sites in Macedonia.—Prof. J. L. Myres (*Chairman*), Mr. S. Casson (*Secretary*), Dr. W. L. H. Duckworth, Mr. M. Thompson. **£50.**

To report on the Classification and Distribution of Rude Stone Monuments.—Mr. G. A. Garfitt (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. O. G. S. Crawford, Miss R. M. Fleming, Prof. H. J. Fleure, Dr. C. Fox, Mr. G. Marshall, Prof. J. L. Myres, Mr. H. J. E. Peake, Rev. Canon Quine.

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.—Mr. E. Torday (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. G. A. Auden, Dr. H. A. Auden, Mr. L. J. P. Gaskin, Mr. E. Heawood, Prof. J. L. Myres.

- To report on the probable sources of the supply of Copper used by the Sumerians.—Mr. H. J. E. Peake (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Prof. C. H. Desch, Prof. H. J. Fleure, Prof. S. Langdon, Mr. E. Mackay, Sir Flinders Petrie, Mr. C. Leonard Woolley.
- To conduct Archæological and Ethnological Researches in Crete.—Prof. J. L. Myres (*Chairman*), Mr. L. Dudley Buxton (*Secretary*), Dr. W. L. H. Duckworth, Sir A. Evans, Dr. F. C. Shrubbsall. **£50.**
- The Investigation of a hill fort site at Llanmelin, near Caerwent.—Dr. Willoughby Gardner (*Chairman*), Dr. Cyril Fox (*Secretary*), Dr. T. Ashby, Prof. H. J. Fleure, Mr. H. J. E. Peake, Prof. H. J. Rose, Dr. R. Mortimer Wheeler.
- To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith (*Chairman*), Prof. J. L. Myres (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Mr. G. A. Garfitt, Miss D. A. E. Garrod, Prof. W. J. Sollas.
- To conduct Anthropological investigations in some Oxfordshire villages.—Mr. H. J. E. Peake (*Chairman*), Mr. L. H. Dudley Buxton (*Secretary*), Dr. Vaughan Cornish, Miss R. M. Fleming, Prof. F. G. Parsons.
- To report on the present state of knowledge of the relation of early Palæolithic Implements to Glacial Deposits.—Mr. H. J. E. Peake (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. H. Balfour, Prof. P. G. H. Boswell, Mr. M. C. Burkitt, Prof. J. E. Marr.
- To co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. A. Leslie Armstrong, Prof. P. G. H. Boswell, Mr. E. N. Fallaize, Dr. R. V. Favell, Prof. H. J. Fleure, Miss D. A. E. Garrod, Dr. A. C. Haddon, Dr. J. Wilfrid Jackson, Dr. L. S. Palmer, Prof. F. G. Parsons, Mr. H. J. E. Peake. **£50.**
- To investigate processes of Growth in Children, with a view to discovering Differences due to Race and Sex, and further to study Racial Differences in Women.—Sir A. Keith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Mr. L. H. Dudley Buxton, Dr. A. Low, Prof. F. G. Parsons, Dr. F. C. Shrubbsall.
- To report on proposals for an Anthropological and Archæological Bibliography, with power to co-operate with other bodies.—Dr. A. C. Haddon (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. T. Ashby, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Prof. J. L. Myres, Mr. H. J. E. Peake, Dr. D. Randall-MacIver, Mr. T. Sheppard.
- To report on the progress of Anthropological Teaching in the present century.—Dr. A. C. Haddon (*Chairman*), Prof. J. L. Myres (*Secretary*), Prof. H. J. Fleure, Dr. R. R. Marett, Prof. C. G. Seligman.
- To conduct explorations on Early Neolithic Sites in Holderness.—Mr. H. J. E. Peake (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Mr. G. A. Garfitt, Dr. J. Wilfrid Jackson, Prof. H. Ormerod, Dr. L. S. Palmer.
- To investigate the antiquity and cultural relations of the Ancient Copper Workings in the Katanga and Northern Rhodesia.—Mr. H. J. E. Peake (*Chairman*), Mr. E. N. Fallaize and Mr. G. A. Wainwright (*Secretaries*), Mr. H. Balfour, Mr. G. A. Garfitt, Dr. D. Randall-MacIver, Dr. P. A. Wagner.
- To arrange for the publication of a new edition of 'Notes and Queries on Anthropology.'—Dr. A. C. Haddon (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mrs. Robert Aitken, Mr. H. Balfour, Capt. T. A. Joyce, Prof. J. L. Myres, Mrs. Seligman, Prof. C. G. Seligman.
- To consider the lines of Investigation which might be undertaken in Archæological and Anthropological Research in South Africa prior to and in view of the meeting of the Association in that Dominion in 1929.—Sir H. Miers (*Chairman*), Dr. D. Randall-MacIver (*Secretary*), Mr. H. Balfour, Dr. A. C. Haddon, Prof. J. L. Myres.
- To co-operate with Dr. Klercker's archæological laboratory in Scania in research.—Mr. H. J. E. Peake (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Prof. H. J. Fleure, Prof. J. L. Myres, Mr. E. K. Tratman.

SECTION I.—PHYSIOLOGY.

The Investigation of the Medullary Centres.—Prof. C. Lovatt Evans (*Chairman*), Dr. J. M. Duncan Scott (*Secretary*), Dr. H. H. Dale.

Colour Vision, with particular reference to the classification of Colour-blindness.—Sir C. Sherrington (*Chairman*), Prof. H. E. Roaf (*Secretary*), Prof. E. N. da C. Andrade, Dr. Mary Collins, Dr. F. W. Edridge-Green, Prof. H. Hartridge.

Ductless Glands, with particular reference to the effect of autacoid activities on vasomotor reflexes.—Prof. J. Mellanby (*Chairman*), Prof. B. A. McSwiney (*Secretary*), Prof. Swale Vincent. **£30.**

SECTION J.—PSYCHOLOGY.

Vocational Tests.—Dr. C. S. Myers (*Chairman*), Dr. G. H. Miles (*Secretary*), Prof. C. Burt, Mr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear, Prof. C. Spearman. **£50.**

SECTION K.—BOTANY.

The effect of Ultra-violet Light on Plants.—Prof. W. Neilson Jones (*Chairman*), Dr. E. M. Delf (*Secretary*).

The Chemical Analysis of Upland Bog Waters.—Prof. J. H. Priestley (*Chairman*), Mr. A. Malins Smith (*Secretary*), Dr. B. M. Griffiths, Dr. E. K. Rideal. (Unexpended balance.)

Transplant Experiments.—Dr. A. W. Hill (*Chairman*), Mr. W. B. Turrill (*Secretary*), Prof. F. W. Oliver, Dr. E. J. Salisbury, Prof. A. G. Tansley.

Breeding Experiments as part of an intensive study of certain species of the British Flora.—Sir Daniel Hall (*Chairman*), Mr. E. Marsden Jones (*Secretary*), Dr. K. B. Blackburn, Prof. R. R. Gates, Mr. W. B. Turrill, Mr. A. J. Wilmott. **£32 2s. 6d.** (unexpended balance).

The Ecology of Selected Tributaries of the River Trent, with a view to determining the effect of progressive pollution.—Prof. F. E. Fritsch (*Chairman*), Prof. H. S. Holden (*Secretary*), Miss D. Bexon, Mr. H. Lister. **£3 16s. 8d.** (unexpended balance).

The Flora of Northern Rhodesia.—Prof. D. Thoday (*Chairman*), Dr. J. Burt Davy (*Secretary*), Prof. R. S. Adamson, Prof. J. W. Bews. **£25.**

To consider the organisation of a body to further the protection of British Wild Plants.—Dr. A. W. Hill (*Chairman*), Dr. H. H. Thomas (*Secretary*), Dr. G. Claridge Druce, Prof. J. W. Heslop Harrison, Mr. H. A. Hyde, Prof. F. W. Oliver, Sir D. Prain, Dr. E. J. Salisbury, Mr. C. E. Salmon, Mr. A. J. Wilmott, Dr. T. W. Woodhead.

To consider and report on the provision made for Instruction in Botany in courses of Biology, and matters related thereto.—Prof. V. H. Blackman (*Chairman*), Dr. E. N. M. Thomas (*Secretary*), Prof. F. E. Fritsch, Prof. S. Mangham, Mr. J. Sager.

Mycorrhiza in relation to Forestry.—Mr. F. T. Brooks (*Chairman*), Dr. M. C. Rayner (*Secretary*), Dr. H. M. Steven. **£50.**

Fossil Plants at Fort Gray, near East London.—Dr. A. W. Rogers (*Chairman*), Prof. R. S. Adamson (*Secretary*), Prof. A. C. Seward. **£25.**

The Morphology and Systematics of certain South African Liverworts and Ferns.—Prof. R. S. Adamson (*Chairman*), Prof. H. S. Holden (*Secretary*), Prof. R. H. Compton, Mrs. M. R. Levyns, Prof. C. E. Moss, Mr. N. S. Pillans. **£12.**

South African Desert Plants.—Dr. I. B. Pole-Evans (*Chairman*), Prof. C. E. Moss (*Secretary*), Prof. R. S. Adamson. **£60.**

SECTION L.—EDUCATIONAL SCIENCE.

To consider the Educational Training of Boys and Girls in Secondary Schools for overseas life.—Sir J. Russell (*Chairman*), Mr. C. E. Browne (*Secretary*), Major A. G. Church, Mr. H. W. Cousins, Dr. J. Vargas Eyre, Sir R. A. Gregory, Mr. O. H. Latter, Miss E. H. McLean, Miss Rita Oldham, Mr. G. W. Olive, Miss Gladys Pott, Mr. A. A. Somerville, Dr. G. K. Sutherland, Mrs. Gordon Wilson. **£10.**

The bearing on School Work of recent views on formal training.—Dr. C. W. Kimmins (*Chairman*), Mr. H. E. M. Icely (*Secretary*), Prof. R. L. Archer, Prof. Cyril Burt, Prof. F. A. Cavenagh, Miss E. R. Conway, Sir Richard Gregory, Prof. T. P. Nunn, Prof. T. H. Pear, Prof. G. Thomson, Prof. C. W. Valentine. **£10.**

The teaching of General Science in Schools, with special reference to the teaching of Biology.—Prof. T. P. Nunn (*Chairman*), Mr. G. W. Olive (*Secretary*), Mr. C. E. Browne, Dr. Lilian J. Clarke, Mr. G. D. Dunkerley, Mr. S. R. Humby, Dr. E. W. Shann, Mr. E. R. Thomas, Mrs. Gordon Wilson, Miss von Wyss. **£10.**

Educational and Documentary Films: To enquire into the production and distribution thereof, to consider the use and effects of films on pupils of school age and older students, and to co-operate with other bodies which are studying those problems.—Sir Richard Gregory (*Chairman*), Mr. J. L. Holland (*Secretary*), Mr. L. Brooks, Miss E. R. Conway, Mr. G. D. Dunkerley, Dr. B. A. Keen, Dr. C. W. Kimmins, Prof. J. L. Myres, Mr. G. W. Olive, Dr. Spearman, Dr. H. Hamshaw Thomas. **£50.**

CORRESPONDING SOCIETIES.

Corresponding Societies Committee.—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Secretaries, the General Treasurer, Mr. C. O. Bartrum, Dr. F. A. Bather, Sir Richard Gregory, Sir David Prain, Sir John Russell, Prof. W. M. Tattersall.

NARRATIVE OF THE SOUTH AFRICAN MEETING.

The invitation to the British Association to hold a meeting in South Africa was given by the South African Association for the Advancement of Science, with the full support of the Government of the Union of South Africa. On July 8, 1926, a deputation from the South African Association interviewed the Prime Minister of the Union of South Africa, General the Hon. J. B. M. Hertzog. As the result of this interview the following cablegram was despatched to the British Association: 'Please convey to His Royal Highness [The Prince of Wales], President of British Association, cordial invitation to British Association from President and Council of South African Association to visit South Africa in 1929.'

On September 3, 1927, a cable was despatched from the Leeds Meeting of the British Association as follows: 'General Committee British Association unanimously and gratefully accepts invitation South Africa, 1929.'

The Union Government allocated to the South African Association a grant of £10,000, of which £6,000 was transmitted to the British Association for distribution in the form of grants, in aid of travelling expenses, to members selected by a committee of the Council, mainly on the nomination of the sectional committees. A sum of about £1,300 was allocated by the South African Association toward the travelling expenses of the President of the British Association and certain selected guests, British and foreign. A sum of £10,000 was collected in Great Britain as detailed in the Report of the Council preceding this narrative (p. xvi), and was devoted to further grants in aid of travelling expenses, and to assist in covering the extraordinary expenses necessarily falling upon the funds of the British Association in connection with a meeting overseas. The Rhodes Trustees generously contributed £250 toward the expenses of certain university students selected by the Committee of Council to attend the meeting. In the Report of the Council referred to above, and in that for the preceding year (*Report of the British Association*, Glasgow Meeting, p. xlii), further particulars relating to the preliminary organisation will be found.

The number of visiting members from overseas was 535. They travelled for the most part in three ships, the Union Castle Mail SS. Co.'s *Llandovery Castle*, the Blue Funnel SS. *Nestor*, and the Union Castle R.M.S. *Windsor Castle*, which arrived at Cape Town respectively on July 18, 19, and 22. The Inaugural General Meeting in Cape Town was held in the City Hall on Monday, July 22, at 4.30 p.m., and was attended by H.E. the Governor-General (the Rt. Hon. the Earl of Athlone) and H.R.H. Princess Alice, the Hon. the Prime Minister, the Minister for Education (Dr. D. F. Malan), Lt.-Gen. the Rt. Hon. J. C. Smuts, and H.M. the Sultan of Zanzibar. Sir Thomas H. Holland, K.C.S.I., K.C.I.E., F.R.S., was inducted into the presidency of the British Association and the chair of the meeting by the Hon. Sir Charles Parsons, O.M., K.C.B., F.R.S., in the unavoidable absence of the retiring president, Sir William Bragg,

K.B.E., F.R.S., from whom a message was read. On taking the chair Sir Thomas Holland read the following message from H.R.H. The Prince of Wales, K.G., F.R.S., ex-president :—

I am glad to recall that invitation to British Association to meet in South Africa was addressed to me during my presidency. Please express to all members my sincere good wishes and hopes for successful outcome of your deliberations.

(Signed) EDWARD P.

To this message the following reply was sent :—

British Association assembled in inaugural session Cape Town gratefully acknowledges receipt of Your Royal Highness's message and shares the hope that scientific deliberations and experiences during visit will benefit permanently both members from overseas and friends in South Africa.

(Signed) HOLLAND, *President*.

Inasmuch as the meeting of the British Association in South Africa in 1929 coincided with the twenty-seventh meeting of the South African Association for the Advancement of Science, the inaugural address was delivered by Mr. Jan H. Hofmeyr, president of the South African Association, on 'Africa and Science' (see page 1). The meeting of the South African Association was thereafter merged in that of the British Association.

The transactions of the sections are summarised in later pages of this report. Sir Ernest Rutherford, O.M., F.R.S., delivered to members of the British and South African Associations an evening discourse on 'The Structure of the Atom' in the Cape Technical College on Thursday, July 25. Numerous public lectures were provided, both at Cape Town and throughout the meeting. By the courtesy of the Broadcasting Company Prof. J. L. Myres, General Secretary, and Mr. O. J. R. Howarth, Secretary, had been enabled, shortly after their arrival (July 15), to inform the South African public as to the objects of the meeting and to summarise its course. Among the public lectures arranged in Cape Town were the following :—

July 17	Prof. Douglas Johnson.	The Face of the Waters.
„ 18	Prof. J. L. Myres.	The Discovery of Iron.
„ 19	Prof. F. E. Lloyd.	Plants that Devour Animals ; and Wigglers and how they wiggle.
„ 24	Prof. W. T. Gordon.	Attractive Minerals.†
„ 26	Prof. D'Arcy Thompson, C.B., F.R.S.	Anatomy from an Engineer's point of view.
„ 27	Mr. G. Fletcher.	Harnessing the Sun's Energy.†

† Especially for young people.

A discussion on Science and Industry was initiated in Cape Town under the chairmanship of the President, and continued in Johannesburg ; the public being admitted. At Cape Town Dr. F. E. Smith, C.B.E., F.R.S., Sir Daniel Hall, K.C.B., F.R.S., Prof. D'Arcy Thompson, C.B., F.R.S., and Sir Richard Gregory took part, and a vote of thanks to the speakers was proposed by Mr. J. H. Hofmeyr.

Throughout South Africa members received most generous hospitality at the hands both of public authorities and of private individuals. Among the entertainments arranged for them at Cape Town special reference may be made to the reception by the Trustees and Director of the South African Museum (July 22), the 'at home' given by the Vice-chancellor and

Council of the University of Cape Town (July 23), the afternoon tea given by the Principal of the Diocesan College, Rondebosch (July 24), the civic reception and conversazione in the City Hall (July 24), the 'at home' given by H.M. Astronomer, Dr. Spencer Jones, at the Royal Observatory (July 25), and the luncheon given by the Union Government at Groot Constantia (July 26). Numerous excursions, general and sectional, gave members opportunity to acquaint themselves with the scientific interests, scenic beauties, and industrial activities of the Cape Peninsula. In connection with the excursion to Stellenbosch (July 27) an 'at home' and luncheon were given by the Vice-chancellor, Council and Senate of the University of Stellenbosch.

Members left Cape Town in two special trains on July 28 and two on July 29. Each party spent the day after its departure from Cape Town at Kimberley, where they were guests of De Beers Consolidated Mines, Ltd. The diamond mines and other features of interest were inspected. Dr. A. E. H. Tutton, F.R.S., lectured on 'Crystals and Atoms' on July 29.

Meanwhile, special arrangements had been carried out by certain sections. Some of the members interested in geology, anthropology, forestry and agriculture had left Cape Town earlier than the main party, in order to devote more time to points of special interest en route to Transvaal. Section C (Geology), after an early meeting in Johannesburg, proceeded to Pretoria for co-operation with the International Geological Congress. Section M (Agriculture) held no meetings in Johannesburg, but proceeded from Cape Town to Pretoria, some members visiting the agricultural college at Potchefstroom en route. At Pretoria the section co-operated with the Pan-African Agricultural and Veterinary Congress.

A forecast of the meeting in Johannesburg was broadcast by the Secretary on July 29.

The two divisions of the main party of visiting members arrived in Johannesburg in the mornings of Tuesday and Wednesday, July 30 and 31. On the Tuesday evening Dr. F. E. Smith, C.B., C.B.E., F.R.S., delivered a public lecture on 'The New Airship R 101' in the City Hall.

The Inaugural General Meeting in Johannesburg was held in the City Hall on July 31 at 8.30 p.m., when Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S., delivered his presidential address on 'The International Relationships of Minerals' (see page 22). The discussion on 'Science and Industry' referred to above was continued on August 2 under the chairmanship of Dr. J. H. Hofmeyr, when Dr. C. S. Myers, C.B.E., F.R.S., Prof. G. W. O. Howe, Sir John Flett, K.B.E., F.R.S., and Prof. A. C. Seward, F.R.S., spoke, and a communication by the Hon. H. Mond, in his absence, was taken as read. Sir Thomas Holland brought the discussion to a conclusion. Miss Caton-Thompson gave a public lecture on 'Zimbabwe' (August 3) and lectures to young people were given by Dr. H. Hamshaw Thomas on 'The Plants of Past Ages' (August 1) and by Mr. E. R. Thomas on 'What is Matter?' Several public lectures were given in municipalities neighbouring to Johannesburg, and in Pretoria. Among many entertainments, the Senate and Council of the Witwatersrand University gave an 'at home' on August 1 and an evening reception was given by the Mayor and City Councillors on the same day. A native war dance was witnessed by the members on August 4. Among the arrangements for excursions,

special reference is due to the action of the Chamber of Mines, thanks to which members had the opportunity of viewing every stage of the Transvaal gold industry, from mining the ore at greatest depths to the recovery of the gold and the casting of ingots, and of acquainting themselves with the accompanying engineering and physiological problems and labour conditions, including the welfare of the native labourers.

At the concluding general meeting in Johannesburg on Saturday, August 3, it was resolved :—

‘That the British Association for the Advancement of Science do thank the South African Nation.’

The President, in introducing the above resolution, made the following statement :—

‘The visiting members of the Association feel that by no less comprehensive phrase could they express adequately their gratitude to the South African Association for the Advancement of Science, at whose invitation they are here in joint session ; to the Government of the Union, without whose powerful aid that invitation could not have been given ; to all administrative departments, municipal authorities, educational, commercial and other institutions which have placed their manifold resources at the disposal of members ; to the many citizens of the Union who have afforded to the visitors such unstinted and thoughtful hospitality.

‘It is the earnest hope and belief of all who have participated in this memorable meeting that the bonds of mutual interest created in 1905 may prove to have been extended and strengthened during the present year and may so continue, to the advancement of science which is the object of both the British and the South African Associations.’

In addition to the President, Sir Robert Falconer and Prof. G. Hevesy spoke to the resolution, as representing respectively visiting members from the Dominions and foreign guests. Dr. J. H. Hofmeyr, President of the South African Association, and Prof. J. H. Wilkinson, Chairman of the Executive Committee in South Africa for the meeting, replied.

TOURS.

Members’ travels in South Africa were arranged by the Tourist and Travel Branch of the South African Railways Administration, which offered a series of tours after the meetings in Johannesburg and Pretoria. The majority of members, apart from those who travelled independently, joined one of the tours known as Nos. 1, 2, 8 and 9. All of these included visits to Victoria Falls and Bulawayo ; the first two included the more comprehensive routes through Union territory ; while the two last, terminating at the port of Beira, were more convenient for those members who desired to return home by the east coast of Africa, visiting the colony of Kenya en route.

Tour 1.

This tour left Johannesburg on August 5 and terminated at Durban on August 18. A day was spent at Pretoria, with visits to the Premier Diamond Mine, Government House, and the beautiful Union building. Two days were devoted to Victoria Falls and one to a call at Bulawayo, from which the granite hill-country of the Matoppos, in which is the grave

of Cecil Rhodes, was visited. In the evening the Mayor of Bulawayo gave a reception, at which His Excellency the Governor was present, and Dr. A. G. Ruston delivered a lecture on 'Success in Agriculture and what makes for it.'

After a few hours spent in Johannesburg on the return journey from the north the party proceeded to the eastern Transvaal, and viewed the orange groves in the neighbourhood of Mataffin and White River, and also the tobacco-curing warehouse of the Barberton District Co-operative Company at Nelspruit. At White River the members were received by the White River Fruit-growers' Co-operative Association and the White River Valley Farmers' Association. An evening reception was given, and lectures were delivered by Dr. Winifred Brenchley on 'The Work of Plant Roots' and by Prof. A. Findlay on 'Cellulose and its Uses.' At Komatipoort members were enabled to see hippopotami in the river, and during their passage through the Sabie Game Reserve (Kruger National Park) they were fortunate in seeing wild game of several kinds under natural conditions. A native dance was witnessed during the evening spent at Sabie Bridge. At Tzaneen members left the train in order to proceed by road to Magoebaskloof and Duivelskloof. Thereafter the train was rejoined, and the next halt was made at Pietersburg (Northern Transvaal) where, at a reception in the evening, Dr. C. Tierney lectured on 'Nature's Secrets' and Dr. B. A. Keen on 'Cultivation Implements from Tree Trunk to Tractor.'

The party next travelled to Pietermaritzburg, Natal, where they were received by the Mayor and leading citizens on Sunday morning, August 18, and in the afternoon they proceeded to Durban. Prof. W. H. Eccles, F.R.S., returned subsequently to Pietermaritzburg to lecture on 'Wireless.'

At Durban a programme of lectures, entertainments and excursions was arranged. On August 15, before the arrival of the main party, Mr. R. B. Forrester had lectured on 'The Stabilisation of Agricultural Prices.' On Monday, August 19, the party was officially welcomed by the Mayor, the bay was viewed from a steamer provided by the South African Railways and Harbours Administration, and members lunched with the Mayor at the Country Club. Dr. Marion Newbigin lectured to young people on 'The Mediterranean Lands,' Prof. A. S. Eddington, F.R.S., lectured on 'The Inside of a Star,' under the auspices of the Natal Astronomical Society and the Durban Library Group, and Prof. E. C. C. Baly, C.B.E., F.R.S., lectured on 'The Photosynthesis of Carbohydrates,' under the auspices of the South African Chemical Institute. On Tuesday, August 19, a number of excursions were enjoyed, a civic reception was given in the Pavilion, and Sir John Russell, F.R.S., lectured on 'The Conquest of the Virgin Lands.' On Wednesday, August 20, there were further excursions, and Prof. E. W. Marchant lectured on 'Michael Faraday and his Successors and the Electric Age,' under the auspices of the Natal Institute of Engineers. Prof. G. W. O. Howe lectured later (August 26) under the same auspices, on 'The Recording and Reproduction of Speech and Music.'

The President, Sir Thomas Holland, was received by the Indian community during his stay in Durban.

On and after Wednesday, August 21, when the first large contingent

left for England, the party broke up. The President presented to the Mayor a valedictory address in the following terms :—

‘ To His Worship the Mayor, the Corporation, and Citizens of Durban.

‘ Those members of the British Association who have enjoyed the hospitality of Durban could not leave Africa with last memories happier than those inspired by their visit here, though that has been all too short. Nor could the applications of science to industry and human welfare be better illustrated than in this new city of less than a century’s development from its foundation to maturity as the third city of South Africa in population, and one of its principal seaports. The excursions kindly arranged by the local committee have shown the visitors something of the activities of the port, with its graving dock, its busy quays, oil sites and whaling station. By visiting the municipal native affairs institutions they have been enabled to learn of the sympathetic treatment of native problems, and among other places of interest they have seen the fine installation at the Congella power station. All these are in effect centres of applied science, and for the teaching of science Natal has in its technical college an institution worthy of all possible support, and destined, as members of the Association hope and believe, to great expansion.

‘ The visiting members most warmly thank Durban for their generous reception, and wish continued and increasing prosperity for the city and the province of Natal.’

The Secretary of the Association, at the request of the President, broadcast from Durban a speech of farewell to South Africa, which was relayed to Johannesburg.

Tour 2.

This tour, leaving Johannesburg on August 7, followed the same route and programme as Tour 1 as far as Victoria Falls, Bulawayo, and the return to Johannesburg. Prof. Sir T. Hudson Beare lectured at Bulawayo on welfare work in the mining industry.

The tour proceeded to Mafaffin and visited the orange groves and the Tomango factory of Messrs. Hall & Sons, and after a few hours at Nelspruit, spent two days at Barberton. The party was welcomed by the Mayor, and a reception was held in the town hall. The party visited the co-operative cotton ginnery, and attended a reception in the evening. Lectures were given by Professor Reynolds on ‘ Volcanoes ’ and by Mr. G. L. Purser on ‘ A Hen’s Egg.’ On the second day the cotton plant research laboratories were visited, after which the party divided, some members going to an amianthus mine, and others motoring up 2,500 feet into the Barberton Hills and, after a picnic luncheon, visiting a native encampment. A lecture was given in the evening by Mr. C. A. Yates on ‘ The Game Reserve,’ with lantern slides from photographs he had taken of various wild animals at their watering place.

After seeing the hippopotami at Komatipoort, the tour passed on into Portuguese East Africa and spent a night at Lourenço Marques, where, by courtesy of the city, members of the British Association were made free of the tramway, and taken for a trip by tugboat round the bay. The

tour then turned west, and stayed for an evening in the Kruger National Park, witnessing a war dance by a camp fire, and, both from the train and on a walk with the forest ranger, seeing a variety of game. The tour was here, and as far as Pietersburg, again following a programme similar to that of Tour No. 1.

On August 20 the tour reached Tzaneen, where the members visited farms in the morning, and in the afternoon were driven through the mountain scenery of Magoebaskloof. An entertainment was given for them in the evening. The tour then went north to Pietersburg, where the party was received by the Mayor, and cars were provided, some of which took members to different farms and others to the native school. In the evening lectures were given by Miss L. Grier on 'Education and Industry in England,' and by Dr. J. H. Arkwright on 'Variations in Bacteria.'

The next day the party arrived at Bloemfontein, where lectures were given at the City Hall on 'The Individuality of the Canadian People' by Sir R. Falconer, and on 'The Geography of some African Plants' by Mr. R. d'O. Good. The Administrator of the Province and the Mayor were present. The following day members were driven round the town, and went over the new University buildings.

The tour then proceeded to Port Elizabeth. Here, in the Snake Park, the visitors saw the attendant gather up handfuls of adders and other poisonous snakes and sling numbers of pythons round his shoulders.

On August 25 the tour proceeded by the Garden Route to Cape Town. A day was spent at Oudtshoorn, where the party walked through the Cango Caves and saw their remarkable stalactite and stalagmite formation. Tea was given to the members on an ostrich farm, and a reception was held in the evening at which the guests were received by the Mayor and Mayoress. The next halt was at Knysna, where, after visiting the "Heads" sea-view, most of the members drove through a primeval forest still inhabited by a herd of elephants. The last day was spent at Mossel Bay, where a tug trip round Seal Island was arranged. After an impromptu entertainment in the evening, the party returned to the train and reached Cape Town on August 29.

Tour 8.

A party numbering 105 left Johannesburg on August 3 and proceeded via Bulawayo, Victoria Falls, Fort Victoria, Zimbabwe and Salisbury to Beira; thence to Zanzibar, Mombasa and Nairobi, from which centre many minor tours were arranged.

From Bulawayo a journey was made to the Matoppos Hills and the grave of Rhodes was visited. Two days were spent at the Victoria Falls and three days at Fort Victoria and Zimbabwe. From Fort Victoria visits were made to local farms, some asbestos and tungsten mines, the local reservoir and power station and other places of interest. At the Zimbabwe ruins Miss Caton-Thompson explained the nature of her discoveries.

The members next proceeded to Salisbury, where they were received by representatives of the Governor, the Mayor and leading citizens. A local committee arranged a number of drives to tobacco and other farms, and in the afternoon the Governor invited members to tea at Government House. In the evening Sir Richard Gregory delivered a lecture on

'Science and Discovery,' which was followed by a banquet attended by the Governor and the Mayor. Prof. A. C. Seward, F.R.S., Dr. C. S. Myers, C.B.E., F.R.S., and the Hon. Sir Charles Parsons, O.M., K.C.B., F.R.S., spoke on the work of the Association.

The next stopping place was Beira, where about eight hours were spent, the party embarking in the S.S. *Khandalla* on the afternoon of August 15. The sea voyage to Zanzibar was ideal, the sea being unusually calm and the sunsets remarkably beautiful. Zanzibar was reached on August 20 at 7 a.m.; the party proceeded ashore in Government launches and visited the Government Offices, the Museum, the bazaars and local markets. A drive of twenty miles through palm and clove plantations took the party to an old royal palace where the Sultan held a reception and gave an open-air lunch. In addition to the Sultan, the Resident and the Sultan's son were present. A second day was spent at Zanzibar, the bazaars being the principal centre of attraction.

Mombasa was reached on Thursday, August 22, the party being received by the District Commissioner, the Mayor and a reception committee. A lunch was given by the European community at the Mombasa Club, and afterwards drives were arranged to places of antiquarian and agricultural interest. Seventeen members of the party stayed in Mombasa for three days and made a tour of the island. On the return journey Prof. F. C. Lea gave a lecture at Mombasa on 'Transport Problems in Kenya,' and Prof. W. E. Dixon, F.R.S., lectured on 'Race Degeneration.'

Nairobi was reached on August 23, members being met by representatives of the Governor (Sir Edward Grigg), the Director of Agriculture (Mr. Holm), Captain Ward and other leading citizens. Throughout Kenya free transport was provided by the Government to all members of the Association, and in Nairobi either free hotel accommodation or private hospitality was provided for all. Ten members of the Association stayed at Government House. From Nairobi a number of minor tours were arranged, most of which were of several days' duration, and no member of the party could possibly partake in all of them. Local places of interest such as the Agricultural and Veterinary Research Laboratories, the Arboretum, the Rift Valley, the Kikuyu Native Reserve and many coffee and sisal plantations were, however, visited by the majority of the party. In Nairobi lectures were given by Prof. E. Mellanby, F.R.S., on 'Vitamins,' by Dr. F. E. Smith, C.B., F.R.S., on 'The New Airship R. 101,' by Prof. G. H. F. Nuttall, F.R.S., on 'Diseases of Animals,' by Sir Richard Gregory on 'Science and Progress,' by Prof. A. Fowler, F.R.S., on 'Sun and Stars,' by Prof. Lea on 'Transport Conditions in Kenya,' and by Prof. J. G. Priestley on 'Vegetative Propagation.'

Thirty members made a four-days' tour to Nakuru, Kisumu and the Kavirondo Native Reserve. Elmenteita was visited, and the work of the East African Archæological Expedition under Mr. L. S. B. Leakey was seen. At Nakuru, Dr. C. S. Myers, C.B.E., F.R.S., gave a lecture on 'Industrial Psychology applied to Agriculture,' and Prof. H. J. Fleure lectured on 'Prehistoric Man in Africa.' Mr. G. Fletcher also gave an address.

Fifteen members spent three days visiting Eldoret and Kitale, passing over the Nasin Gishu Plateau, where maize, sisal and coffee are extensively

grown. At Eldoret Prof. W. G. Ogg gave a lecture on 'Soils.' A third party numbering about thirty made a three-days' tour in a fleet of cars to Nyeri and Nanyuki. The slopes of Mount Kenya were of great interest to the botanists, as the district has a plentiful supply of camphor, yellow wood and bamboo trees. Mr. Horne, the District Commissioner, conducted ten members through sixty miles of the Native Reserve, and the Nyeri Reception Committee gave a dinner to the whole party at the Outspan Hotel. At the Rhino Hotel Dr. A. B. Rendle, F.R.S., gave a lecture on 'Preservation of Natural Flora,' and a lecture on 'Transport' was given by Prof. F. C. Lea.

A fourth party paid a three-days' visit to Navaisha, Elmenteita and Nakuru, and twelve members visited Lake Magadi, passing through the Masai Reserve and Game Reserve to the great Soda Lake.

On August 29 a banquet was given at Nairobi by Councillor Chas. Udall (the Mayor) and the Municipal Council to all the members visiting Kenya. Lieut.-Colonel Sir Edward Grigg, the Governor, was present. Addresses of welcome were given by the Governor and the Mayor, and the thanks of the Association for the magnificent reception of its members were expressed by the Hon. Sir Charles Parsons, O.M., K.C.B., F.R.S., Prof. A. C. Seward, F.R.S., and Miss E. R. Saunders. The following farewell message was printed in the *East African Standard* on August 31 :—

'On the eve of our departure from Nairobi, we members of the first party of the British Association desire to express our grateful appreciation of the generous hospitality which has been afforded to us on all sides during our visit to Kenya Colony.'

'It is not too much to say that in the hearts of every one of us is a feeling of regret that we have not been able to remain here for more than a few days. All the members of all the local tours are enthusiastic as to the wonders they have seen, both natural and as the result of man's enterprise and industry. We all feel here, more than in any other territory which we have visited since leaving Cape Town, that we are in a characteristically British Colony. If there be any other place in the British Empire which reminds us of home and our own particular social life more than Kenya Colony then to all of us it remains unknown.'

'We have been profoundly impressed by the possibilities of immense development afforded by the natural features, climate and soil of the Colony, and it is our fervent hope that the British community which has established itself so successfully here will preserve the same type in future years so that Kenya Colony may be a pattern of what life overseas has to offer to the many settlers who will assuredly be attracted to it in increasing numbers.'

The party left Nairobi on August 30 and Mombasa on August 31, and proceeded homewards via the Red Sea. A flying visit to Cairo was made by thirty members.

Tour 9.

This tour left Johannesburg on August 9, and followed the same route as Tour 8.

At Fort Victoria the party divided into two groups, one going direct to Zimbabwe, whilst the other remained in Fort Victoria and *vice versa*, two days being spent at each place.

At Fort Victoria motors enabled the visitors to reach various farms and mines, where they were hospitably received. Two evening lectures were given at Fort Victoria, one by Prof. A. F. Barker on 'Some Problems relating to Wool,' and one by Mr. J. A. Venn on 'The Economics of Farming.'

One night was spent at Salisbury, where Sir Robert Greig gave a lecture on 'Some Agricultural Contrasts.' After the lecture the members were guests of the municipality and of the Rhodesia Scientific Association at a reception supper at the Grand Hotel.

The train left for Beira next morning, and at the request of the people of Umtali was accelerated so as to enable the party to have a short space of daylight at that place. Many cars met the train at Umtali and took the visitors to the top of Christmas Pass and round the town before darkness set in. Then the party was received at the public hall by the Mayor and the local scientific society.

The S.S. *Matiana* carried the party from Beira to Mombasa, calling en route at Dar-es-Salaam, Zanzibar and Tanga.

Only a few hours were spent at Zanzibar, where the visitors were taken ashore by the Sultan's launches. Various British residents showed them the town and drove them out into the country to see the coconut and clove plantations, and then entertained them to dinner at their houses.

Mombasa was reached on August 9, and about thirty members of the party broke their journey there and remained in Kenya Colony for over a fortnight as its guests. The remaining members of Tour 9—including a few who had left the boat at Tanga and travelled by rail round the foot of Kilimanjaro to Voi in Kenya Colony—made a hurried trip to Nairobi. They then rejoined the *Matiana*, in which they returned to England together with the members of Tour 8.

The thirty members of Tour 9 who stayed in Kenya Colony were welcomed and treated most hospitably by both official and private residents, and were given unrivalled facilities for seeing as much as possible in the time at their disposal. On September 3 Dr. Ethel N. Miles Thomas gave a lecture in Nairobi on 'Some Problems of Inheritance,' Sir Daniel Hall and Mr. W. G. Ogg on the afternoon of September 10 lectured on 'Soil Problems' at Nairobi, while Prof. H. Bassett lectured on 'Recent Chemical Discovery and its Bearing on Industry' at Nairobi on September 11, and at Mombasa on September 14. The evening before leaving Nairobi (September 12) the party was entertained to a banquet given at the new Stanley Hotel by the Mayor and Municipal Council. Sir Daniel Hall was left behind in Nairobi to act as chairman of a commission on Agriculture. The main party returned to England on S.S. *Durham Castle*.

It will have been observed that during the tours described above many members delivered lectures to local audiences. Such lectures, given in response to requests from many towns and institutions, proved a special feature of the visit to South Africa; for, in addition to those mentioned, others were given in response to invitations received not only by the Association but by individual members, and not only in Cape Town and Johannesburg, but in a number of important centres additional to those named in preceding paragraphs.



BRITISH ASSOCIATION FOR THE ADVANCEMENT OF
SCIENCE.

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT
OF SCIENCE.

AFRICA AND SCIENCE.

ADDRESS BY

JAN H. HOFMEYR, M.A.,

PRESIDENT OF THE SOUTH AFRICAN ASSOCIATION,

ON THE OCCASION OF THE INAUGURAL MEETING IN CAPE TOWN, JULY 22, 1929.

TO-NIGHT I enter upon the consummation of what is at once the highest and the least merited distinction which it has been my privilege to receive. To those who called me to the office of President of the South African Association for the Advancement of Science I tender my sincere thanks. I make myself no illusions in respect of the adequacy of my claims to that honour on the ground either of scientific attainment or of services rendered to the cause of Science, nor would I have our visitors remain for a moment without the knowledge that my scientific qualifications for this Presidential Chair are of the slightest. They are far less indeed than those of that distinguished statesman to whom when he had remarked to the great Faraday in relation to an important new discovery in Science, 'But after all, what is the use of it?' the scientist replied, 'Why, Sir, there is every probability that you will soon be able to tax it.' The Presidency of this Association is an honour the conferment of which upon myself has never seemed to fall properly within the scope of my ambitions; it imposes responsibilities for the discharge of which I am all too scantily equipped; and I can only seek to justify my election in a manner similar to that which Mr. Stanley Baldwin followed when he was chosen to be President of the Classical Association in England. I can but say that, while it is to the scientist that we look for the advancement and the progress of Science, the effectiveness with which his work is brought to fruition does depend in some measure on the interest, the sympathy, and the enthusiasm, with which his achievements are followed up by that army of plain, ordinary men, in which I gladly count myself a musket

bearer. In no other capacity dare I venture to address you. It was once said by a literary man of some distinction that the man of science appears to be the only man in the world who has something to say, and he is the only man who does not know how to say it. There is an obvious rejoinder, that the man of letters frequently has nothing to say, but says it at great length. I dare not claim to be a man of science. I can only hope that I shall not be deemed to-night to have qualified for consideration as a man of letters in the sense of that retort.

The honour which has been conferred upon me is the greater because of the special significance which attaches to my year of office. It is the year of the keenly anticipated second visit of the British Association for the Advancement of Science to South Africa, and for that reason my first words to-night are, happily, words of welcome. Not merely the Association for which I speak, but all South Africa, rejoices in the presence of the British Association and its distinguished members. To its parent body, which can look back upon all but a century of glorious achievement, this stripling Association brings its tribute of respectful admiration and goodwill. To the great organisation of scientific men, the history of which is the history of the advancement of Science in Britain, which has a Presidential Roll adorned by names such as Brewster and Tyndall, Huxley and Kelvin, Rayleigh and Lister, this land of ours, mindful of its debt to Science, conscious of the gifts that Science can yet bring to it, extends the hand of friendship, in gratitude for the honour of this visit, and in appreciation of the stimulus to its progress and development which must needs attend it.

We have reason, indeed, to be grateful to the British Association for its achievement and its significance. If I might select three distinctive features in its record, they would be these. First, its contribution, direct and indirect, to those great triumphs of British Science in the nineteenth century which are the possession not of an age, nor of a nation, but of all time and of every land. Directly it has initiated, correlated, and contributed towards work of great scientific value; indirectly it has inspired much constructive activity, while its meetings year after year have done more than any other single factor to stimulate and hasten the onward march of science.

Next I would dwell on its maintenance of a broad view of the scope and function of Science, and, coupled with that, the emphasis laid by it on the essential homogeneity of Science conceived thus broadly, and the interdependence of its several branches. The Association had no lack

of opposition to encounter at its coming to birth. Those who interpreted Science primarily in the mediæval sense as being limited to the sciences of introspection had still but scant respect for the claims of the sciences of observation. When in the second year of its existence the Association visited Oxford, Keble protested vigorously against the University's reception of what he called a hodge-podge of philosophers. This hodge-podge, be it noted, included Brewster and Dalton and Faraday. But the Association did not react into narrowness. It remained true to the broad conception of *Scientia* which was held by its founders, one of whom affirmed in striking language at the first meeting, that 'The chief interpreters of nature have always been those who have grasped the widest fields of inquiry, who have listened with the most universal curiosity to all information, and felt an interest in every question which the one great system of nature represents.' The Association has imposed no narrow restrictions on the extension of the sphere of its activity; within that ever-widening sphere it has maintained a spirit of co-operation between workers in diverse fields which has been worthy of the best traditions of Francis Bacon. It has had its reward—in greater effectiveness of work in its own sphere, and in the permeation of the Kingdom of Learning with the atmosphere of goodwill. By way of illustration of this last point, may I, as one whose first allegiance is to the Classics, mention the fact that the roll of twenty-six Presidents of the Classical Association of England includes five Fellows of the Royal Society, names such as Geikie, Osler, and D'Arcy Thomson, and if it is not too presumptuously personal to refer to it, I would add, that when the South African Association elected me as its President, it chose one who was then President of the Classical Association of South Africa.

Lastly, I would select as characteristic of the British Association its success in maintaining the contacts of Science with the public on the one hand and the state on the other. One of the aims which its founders set forth was 'to obtain more general attention for the objects of Science'; they sought to create a body which would make its appeal to the educated public as a whole, to fashion an instrument for the interpretation of the sometimes highly technical results of scientific investigation to the man in the street. They realised that the scientist received much from the public, that to the public he must freely give, and that the giving would not be without its due reward of new inspiration and renewed enthusiasms. There were some who opposed the nascent Association in the fear that Science might degrade itself by making too popular an appeal. That

fear has been belied in the passing of the years. The Association has kept touch with the public, it has 'demonstrated to all men that Science is thinking with them and for them,' it has secured their interest and their sympathy, but it has never paid for that achievement the price of a lowering of its aims or of its standards. It is its success in this respect that has secured for it the prestige which has enabled it time and again to stand forth as the ambassador of Science to the state, and so to play an important part in initiating and furthering enterprises of great national and scientific significance.

For these reasons and for much else South Africa is proud and happy to be able to welcome and do honour to the British Association for the Advancement of Science. We welcome it the more heartily because of our consciousness of the greatness of our indebtedness to the first visit of the Association twenty-four years ago. To that visit, with which there will always be linked a name honoured in the history of South Africa, as it is in the annals of Science—I refer to Sir David Gill—this country still looks back with grateful recollection. It marked the commencement of an epoch in our scientific history, the epoch of the consolidation of the position of Science in South Africa.

Let us view the position of Science in our country as it was in 1905. On the academic side it is the nakedness of the land that chiefly impresses us. South Africa then had but one University, and it was in reality only a Board of Examiners for the candidates presented by various Colleges, which were all, without exception, inadequately staffed and poorly equipped. In the subjects which fell within the scope of the Association, as it was defined in 1905, there were in all the Colleges taken together in that year only forty-nine workers, thirty-three professors, and sixteen others. When it is remembered that this was the total number of teachers of all branches of Science spread over seven different institutions, all purporting to do University work, it is painfully obvious how little time was available for scientific research and investigation. Nor was the work done, measured in terms of the number of graduates, very impressive. The number of those who in 1905 qualified for degrees in Pure and Applied Science was only twenty-seven. Outside of the Colleges scientific workers were to be found mainly in Government Departments, then still small and inadequately staffed, and working in isolation in the four South African Colonies. In most branches the State's scientific activities were still in their earliest infancy. The organisation was only just commencing to be built up. As part of these activities there fall

to be mentioned the two astronomical Observatories at that time in operation: the Royal Observatory at Cape Town, then already full of years and of honour, and the Johannesburg Observatory which, thanks largely to the representations made by this Association of ours, had been established a few months before the 1905 meeting. In regard to Scientific Societies there is but little to record. There were in existence in 1905 a small South African Philosophical Society (now known as the Royal Society of South Africa), the Geological Society of South Africa, the Cape Society of Engineers, the Chemical Metallurgical and Mining Society, and also this Association for the Advancement of Science, which had come into existence a bare three years previously. It was, indeed, the day of small things, and small also was the achievement which Science in South Africa at that date had to its credit. If one leaves out of account the work of Sir David Gill and the scientific endeavour which had been put into the development of the gold mining industry of the Witwatersrand, there is little indeed of permanent significance that remains.

Against this picture it is appropriate to set the picture of South African Science as it will unfold itself to our visitors to-day. They will find three vigorous single-College teaching Universities, which have in recent years made remarkable progress in the attainment of the standards of similar institutions in older lands, and also a federal University with six constituent Colleges, which, like the single-College Universities are, in human and material equipment and in the output of the results of scientific investigation, very far ahead of their predecessors of 1905. Against the forty-nine workers of 1905 we can now set 467—144 professors and 323 others—within the range at present covered by the activities of this Association. The twenty-seven graduates of 1905 have increased to 314 in 1928. To the Scientific Societies of 1905 there have been added, since the last visit of the British Association, the South African Institute of Electrical Engineers, the South African Institution of Engineers, the Cape Chemical Society, the South African Chemical Institute, the Botanical Society of South Africa, the South African Biological Society, the Astronomical Society of South Africa, the South African Geographical Society, and the South African Economic Society, and this Association of ours has become an active, vigorous, and powerful body, proud of the achievements which it already has to its credit, challenging eagerly the tasks that await it in the future. The two Observatories of 1905, our visitors will find, have increased to six, including the Smithsonian Solar Observatory in South-West Africa, and the equipment of these institutions

includes four great telescopes, with objectives of 27 inches, $26\frac{1}{2}$ inches, 26 inches, and 24 inches respectively, to which will shortly be added a 24-inch refractor and a 60-inch reflecting telescope—surely a remarkable astronomical equipment for so young a country. The stimulus of the 1905 visit, in which so many prominent European astronomers participated, has indeed borne rich fruit in the advancement of astronomical work in South Africa.

But perhaps our visitors will be impressed not least by the development and consolidation of the scientific departments of our Civil Service, by the magnificent Institute of Veterinary Research which the state has created at Onderstepoort and the effective work which through its scientific officers it is doing for the development of South Africa, and by the remarkably efficient and well-equipped Institute for Medical Research at Johannesburg, the credit of the establishment and maintenance of which falls jointly to the Government and the Mining Industry. Significant also of the attitude of the state to Science, and full of promise for the future, has been the establishment of a Research Grant Board, which advises the Government on the practical measures necessary for the encouragement of scientific research in the Union, and acts as its agent in the distribution of grants in aid of individual investigations.

Nor have we reason to be ashamed of the positive achievements of Science in South Africa during the past quarter of a century. Most impressive, perhaps, regarded cumulatively, have been the advances made in our knowledge of the diseases of plants, animals, and men, and of the methods of preventing them. In 1905 we knew practically nothing of the plant diseases of South Africa. In that year the first steps were taken towards their scientific investigation. To-day a general survey has been completed, most of the important diseases have been worked out, and a highly efficient service for combating them is in operation. In 1905 also the Transvaal Crown Colony Government voted £1,500 as a first instalment towards the establishment of a laboratory for the investigation of stock diseases. From that has sprung the magnificent body of work in veterinary science, which has won world-wide recognition for the Onderstepoort Institution which I mentioned a moment ago. More recently there has been founded the South African Institute for Medical Research, to which is allied the Miners Phthisis Medical Bureau. The researches conducted there in the control of pneumonic infection, and the advances made in industrial hygiene in the fight against silicosis, have

brought great lustre to these two institutions and to South Africa. But in other fields also South African scientific workers have won recognition. In Geology, Marine Biology, the Mathematical Theory of Determinants, the Economics of Gold Production, and along several other lines of investigation, important scientific work has been done in South Africa; a succession of discoveries has been made throwing light on the origins of the human race; and applied science has by means of the conquest of distance in this far-flung land of ours, and of the construction of important irrigation and other engineering works, contributed generously to South Africa's progress. It may, perhaps, be taken as a measure of the achievement of Science in South Africa in one of its aspects that, while in 1906 the value of products of the land exported from South Africa amounted to £5,928,000, the corresponding figure for 1927 was £27,815,000.

But if I were asked to select the most broadly significant feature in the development of Science in South Africa since 1905, I think I would pick out what one might describe as its South Africanisation. In 1905 Science in South Africa was in large measure exotic. The workers had come almost exclusively from other lands. They were only beginning to apply themselves to our South African problems. In many cases they had not yet acquired a South African background, nor a South African outlook. In the years that have passed South Africa has claimed those workers for her own, and they have given themselves to her service. They to whom this is the land of their adoption, no less than those to whom it is the land of their birth, and whom they have taught and inspired, have made it the land of their vigorous and devoted service. In its personnel Science in South Africa has become essentially South African. And Science has given itself with enthusiasm to the problems of South Africa. It has emphasised the specific contributions of South Africa to the wider problems of Science, it has applied itself to the removal of those obstacles which hamper the material development of South Africa, it has taken up vigorously the study of South African Economics and Sociology and Anthropology. Perhaps also one may claim that it has brought to bear on scientific investigation what we regard as the distinctive features of the South African outlook—freshness and breadth of view, receptivity to new illuminations, and readiness to see old truths in new settings and in the light of their wider bearings. Is it not South Africa that has given to Science and the world the conception of Holism? And there is surely no gift more worthily representative of the South African outlook at its

best that we could have offered. It may indeed be that that very South Africanisation of our South African Science of which I have been speaking is but another instance of the Holistic principle at work. As I speak of the South African outlook in Science, I cannot but refer you with that deep appreciation which I know we all feel, to the masterly address which four years ago General Smuts delivered from this chair, when he demonstrated in so compelling a manner (I quote his own description of the task he set himself) 'that there is something valuable and fruitful for Science in the South African point of view, that our particular angle of vision supplies a real vantage point of attack on some of the great problems of Science; and that, so far from the South African view-point being parochial in Science, it may prove helpful and fruitful in many ways to workers in the fields of scientific research and investigation.'

Science in South Africa, then, has made itself truly South African, and in doing so it has established itself in the admiration and affection of the people of this land. As a nation we are grateful to our scientists for their contributions to our intellectual and material progress. The liberal policy of the state in supporting scientific effort we heartily endorse, the increase in the mental stature and the prestige of the nation which Science brings to us we sincerely welcome. We are proud of our South African Science, not least because we know that we can regard it as distinctively ours. But while our Science has been South Africanised, we can rejoice that there is nothing narrow about its South Africanism. Were it otherwise, it would have been false to the spirit of Science. In applying itself to the problems of South Africa, it has succeeded in attracting the attention of the scientific world to South Africa. In that address to which I have already referred, General Smuts emphasised the fact that recent events had drawn the eyes of the world to this land of ours as a rich field for scientific investigation. 'The scope for scientific work,' he said, 'in this department of knowledge' (he was referring more especially to Human Palæontology, but his words are of wider applicability) 'is therefore immense; the ground lies literally cumbered with the possibilities of great discoveries. . . . Science has in South Africa a splendid field of labour; other nations may well envy us the rich ores of this great "scientific divide" which is our heritage.' Those words are well worth remembering. We speak sometimes of our wealth in South Africa—mineral wealth, agricultural wealth, potential industrial wealth—but great also is our scientific wealth, and great is the debt we owe to South African Science for what it has done to reveal that wealth to ourselves and to the world.

There, then, in brief outlines, all too imperfectly drawn, is a picture of South African Science in 1929. Contrast it with the picture of 1905, and you have the measure of the achievement of a great epoch. Science consolidated, Science South Africanised, Science recognised as of great national value, both in the spiritual and in the material spheres, Science drawing to our country the eyes of the world—surely that is no unworthy achievement. And as to-night, once again after the lapse of many days, our Association makes its report to the parent body, to which it gladly pays the tribute of filial reverence, it does so with pride and satisfaction in the work of the intervening period, but also with grateful recognition of the inspiration which that visit of 1905 brought to South Africa as one of the constitutive factors in the progress of the last quarter of a century.

And now it has been our privilege to welcome this second visit of the British Association. Is it strange if we ask ourselves, as we gratefully remember the stimulus of 1905, what will be the stimulus of 1929? That visit had abiding results. What will be the results of this one? That visit inaugurated a new epoch. Are we not justified in believing that once again we stand on the threshold of a great advance? If that be so, what are to be the characteristics of the period on which we are now entering, what will be its achievement? In the period that followed the first visit of the British Association we South Africanised Science in South Africa. Is it too much to hope that in the next we shall Africanise it? Will not this visit perhaps give us the impulse and the inspiration to a bigger and a bolder enterprise? One of the most significant tendencies evidenced in South Africa in the last few years has been the growing consciousness of our obligations in relation to the Continent of Africa. We have come to realise that the position of this European civilisation of ours set upon the verge of this great continent is a position of unique strategic importance, that it presents us with at once an opportunity and a challenge. While in the past we thought, as a nation, almost exclusively of our own problems and difficulties, we are now ceasing to limit our horizon by the Limpopo, we are beginning to envisage the task that awaits us beyond our own borders. And in the mind of the nation there is being developed a new conception of South Africa, of a South Africa that consciously and deliberately seeks to play its part on the African continent, not aiming at conquest or domination, but never failing in its readiness to give its intellectual and material resources to aid all who are engaged in the task of developing this great undeveloped area of the earth's surface, which is so full of potentialities for the future welfare of the world. If then

South Africa aspires to leadership in Africa in other branches of activity, why not also in Science? If the outlook of the nation is broadening, why should not its scientists also begin to think in continents? If as a people we are anxious to make our contribution to Africa, eager to give it of our best, rather than to get from it that which will be to our material advantage, why should not our Science also become consciously and deliberately African in its outlook, its ideals, and the tasks to which it applies itself. If Science has consolidated its position in South Africa, as we believe it has, is it not fitting that, with South Africa as its base, it should enter now into the new sphere of opportunity and achievement which stretches mightily outwards from its borders?

To you, our visitors, I look to give us the stimulus and the encouragement to that enterprise. You have come to Africa. This great land-mass which has reared itself against time's passage, almost since time's beginning, and holds inviolate so many of the records of that passage, has challenged your attention. You have come to Africa to seek new inspiration for the study of the problems that interest you, by seeing them against a different background which has for many of you an unaccustomed vastness. But while Africa was your goal, you did not think fit to enter it at the point nearest to your homes. You steamed down, day after day, skirting the long coast-line of this vast expanse of veld and forest, and have entered it by its Southern gateway. For a great body of scientists, it is the only point of effective entry into Africa. It is by way of this Southern gateway that Science itself can most effectively be made to permeate Africa. And to you, having so come, to you, the ambassadors of Science, I present—Africa. It is Africa and Science, which, I would like to think, are to-day met together. Happy indeed should be the fruits of the mating.

It is to that theme—Africa and Science—that I propose now to invite your attention. What can Africa give to Science? What can Science give to Africa? Those are the questions to which I would address myself. But as I speak, I would ask you all to remember, that it is for the South African scientist that the answers to these questions have primary significance. It is for him that they have significance, because for the solution of many of the problems of South Africa a greater knowledge of Africa as a whole than is at present available is essential, and the extension of that knowledge is his personal responsibility. It is for him that they have significance because he dwells in a land which is strategically placed for attacking the problems of Africa and for drawing forth its hidden resources of scientific discovery for the enrichment of Science throughout the world.

What then can Africa give to Science? In reply to that I can do no more than suggest some of the lines along which Africa seems to be called upon to make a distinctive contribution to Science.

First there are the related fields of Astronomy and Meteorology. To Astronomy I shall but make a passing reference. This continent of Africa, more especially the highlands of its interior plateau, with its clear skies and its cloudless nights, offers wonderful facilities to the astronomer. As proof of the necessity of utilising those facilities, especially with a view to the study of the Southern heavens, I need but quote the words used by Professor Kapteyn on the occasion of the 1905 visit: 'In all researches bearing on the construction of the universe of stars, the investigator is hindered by our ignorance of the Southern heavens. Work is accumulating in the North, which is to a great extent useless, until similar work is done in the South.' Africa has to its credit considerable achievements in the past in the field of astronomical research. The increased equipment now available should make it possible to increase greatly the amount of systematic work now being done, and to offer important contributions to astronomical science.

But probably of greater importance is the work waiting to be done in Meteorology. Few branches of Science have a more direct effect upon the welfare of mankind—that is a lesson which we in South Africa should have learnt only too well—but in few has less progress been made. And in meteorological work Africa is probably the most backward of the continents. It is not so long since Dr. Simpson of the London Meteorological Office declared that, save from Egypt, his office received practically no meteorological information from the great continent of Africa. Moreover, the backwardness of Meteorology is in large measure due to the intricacy of the problems involved, and the necessity of having world-wide information made available. The problems of Meteorology are emphatically not the problems of one country or of one region. The South African meteorologist must see his problems *sub specie Africae* (the seasonal changes in South Africa depend on the northward and southward oscillations of the great atmospheric system overlying the continent as a whole); and quite apart from what he can learn from the rest of Africa, the Antarctic regions have much to teach him. But while the development of meteorological research throughout Africa is of supreme economic importance for Africa, Africa in its turn has its contributions to make to other continents. In particular should we not forget the close interrelation of the meteorological problems of the lands of the Southern hemi-

sphere. The central position of Africa in relation to those lands gives not only special opportunities but also special responsibilities for meteorological observation and research. For the sake both of South Africa and of Science in general I would venture to express the hope that this second visit of the British Association will give as powerful a stimulus to Meteorology as did the first to Astronomy.

Next, I would refer to Africa's potential contributions to Geological Science. Africa is a continent, portions of which have always had a special interest for the geologist because of the great diversity of the geological phenomena manifested, and the vast mineral wealth which, as its ancient workings so abundantly prove, has attracted man's industry from the very earliest times. But in our day the opportunities which it offers to the geologist to make contributions to the wider problems of Science are coming to be more fully realised than ever before. Of special interest in this connection is the light which African Geology, more especially in the form of the study of ancient glacial deposits, can throw on the Wegener hypothesis of continental drift. In the past our geologists have thought mainly of the correlation of our formations with those of Europe. It is time that they paid more attention to their possible affiliations with those of the continents to east and west of us. If Geology can establish the hypothesis that Africa is the mother continent from which India, Madagascar, and Australia on the one side and South America on the other have been dislodged, it will give a new orientation to many branches of scientific activity. For that investigation also Africa occupies a central and determinative position in relation to the other continents, such as we have noted to be the case in the sphere of Meteorology. There are many other geological problems on which Africa can probably shed much light. There is, for instance, the constitution of the earth's deeper sub-strata, in regard to which, as Dr. Wagner has recently pointed out, the study of the volcanic Kimberlite pipes, so numerous throughout Africa south of the Equator, and of the xenoliths they contain, including the determination of their radium and thorium contents, may be of the greatest significance. There is the possibility that the exploitation of Africa's great wealth in potentially fossil-bearing rocks of presumably pre-Cambrian age will yet yield us remains of living beings more primitive than any yet discovered; there are the great opportunities of study which the African deserts offer in the field of desert Geology and Morphology; and there is the assistance which African Geology has rendered to vertebrate and plant Palæontology, and can render to African Anthropology in the investigation of this great

museum of human remains and relics, which we call the continent of Africa.

I pass on to Medical Science. I have referred already to the contributions to the study of the problems of industrial medicine and hygiene which the special circumstances of the South African gold mining industry have made possible. Those contributions have, we may well hope, but prepared the way for advances of a revolutionary character in the early detection, prevention, and treatment of all forms of respiratory disease. But even greater are the opportunities which the continent of Africa offers for the study of tropical diseases, of which it may well be described as the homeland. In Africa there have been and necessarily must be studied the problems connected with malaria, blackwater fever, sleeping sickness, yellow fever, and many other scourges of civilisation, and from Africa there may well come hope and healing for mankind. There are other problems of Medical Science for the study of which Africa is uniquely fitted. There are the physiological questions, important also from the political point of view, which bear on the fitness of the white races to maintain a healthy existence in tropical surroundings, at high altitudes, and in excessive sunlight. For these investigations the diversity of conditions prevailing in the various regions of the African continent make it a magnificent natural laboratory. There is the elucidation of the factors which account for the varying susceptibility of white and coloured races to acute infectious diseases, tuberculosis, and certain types of malignant disease, together with the light which such elucidation may throw on the physical and chemical composition of the human body. Lastly, I would mention the exploration of that most interesting borderland between Psychiatry and Psychological Science by an analysis of the mentality of the diverse African peoples. That investigation has an important bearing not only on the limitations and capacities of racial intelligence, but also on the methods which the ruling races in Africa should follow in seeking to discharge their obligations towards their uncivilised and unenlightened fellow-Africans.

Closely linked with Medical Science is the study of Animal Biology. In some instances the problems of the two branches of Science are to be approached along parallel lines; in others biological investigations are fundamental to the growth of Medical Science; of no less significance is that unity which there is in nature, making it possible for the truths of Animal Biology to be translated into facts concerning mankind. In the African continent there is no lack of opportunity to advance Science by

physiological inquiries into animal structure, by the isolation of the parasites of human and animal diseases, and by the tracing of the life histories more especially of the minuter forms of animal life. 'Nowadays' in the words of Professor J. A. Thomson, 'the serpent that bites man's heel is in nine cases out of ten microscopic.' But scarcely less important are the extensive facilities which Africa still offers for the study of the habits and behaviour of the larger mammals. The naturalistic study of these animals, not as stuffed museum species, but in the laboratories of their native environment, has received all too scanty attention from the scientist, and this is a reproach which African Science, with its rich dowry of mammal and primate material, may confidently be expected to remove. Nor will this study of animal behaviour, especially of those animals which approach nearest to the human type, be without its bearings on our investigations of the workings of the human mind. If in this hasty survey I may take time to mention one more point within this field, I would refer to the results which await the intensified activity of the marine biologist and the oceanographer in the as yet all but virgin territory of the African coast-line. This Association of ours has long dreamed of an African Marine Biological Station as broad in its conception and comparably as useful from the wider scientific and the more narrowly economic points of view as those of Plymouth or Naples or Woods Hole, and withal a rallying point for the naturalist, the zoologist, the botanist, the geographer, the anatomist, the physiologist, indeed for all those workers whose diverse problems meet at the margin of the sea.

From Animal Biology we pass by an easy transition to Anthropology, the study of man himself. And here Africa seems full of splendid promise of discovery that may verify Darwin's belief in the probability that somewhere in this land-mass was the scene of nature's greatest creative effort. It would seem to be not without significance that Africa possesses in the chimpanzee and the gorilla those primate types which approach most nearly the form and structure of primitive man. To that must be added that in the Bushman, Pygmy, and negroid races Africa has at least two and possibly three early human stocks which are characteristically her own and belong to no other continent. No less striking is the fact that in Gibraltar, in Malta, and in Palestine, that is, at each and every one of the three portals into Africa from Europe and Asia in Pleistocene times, there have been discovered evidences of the presence of Neanderthal man. In Africa itself there was found at Broken Hill some nine years ago a skull with the most primitive or bestial facial form

yet seen, and so closely akin to the Neanderthal stock as to establish firmly the expectation of finding further compelling evidence of a long continued Neanderthaloid occupation of the African continent. The discovery at Taungs on the one hand, which reaches out towards the unknown past, and the finds at Boskop and in the Tsitsikama on the other, which assist in linking up the period of Rhodesian man with the coming of the Bushfolk, open up to us, in conjunction with the aforementioned facts, a vista of anthropological continuity in Africa such as no other continent can offer. The recent investigations in the Great Rift Valley, near Elementeita in Kenya, and the fossil discoveries on the Springbok Flats, north of Pretoria, have again fixed the attention of the anthropologist on Africa.

Nor are the data presently available restricted to these discoveries. The efforts of archæologists, and the application of improved scientific methods in excavation, are giving us stratigraphical evidence of the succession of stone cultures which is of the utmost importance. I have already mentioned the assistance which Geology can render in this work, but there is needed also the co-operation of those who labour in the converging fields of Anatomy, Archæology, Palæontology, and Comparative Zoology. That co-operation has already commenced. In the investigation of the Vaal River gravels it has yielded important results, and we may look forward to its continuance and expansion in the years that lie ahead. Of the importance of African Anthropology for the understanding of that of Europe there can be no question. Work of importance has already been done in the study of the relations between Palæolithic Art in Europe and Palæolithic Art in Africa. The significance of these comparisons is but emblematic of the importance of similar investigations in regard to stone cultures, rock engravings, ancient mining, stone circles and ancient ruins, methods of primitive mining and agriculture, tribal organisation, laws and customs, indeed the whole range of the hitherto unexplained or partially explained phenomena of living and extinct cultures. There is no lack of avenues which the student of African Anthropology may follow in the hope of finding at the end of them results of supreme value for Science in general.

I would speak next of the vast field, as yet almost uncharted, of phonological and philological study. Here in Africa we have great opportunities for the examination of linguistic problems, and some of them have bearings which extend far beyond the limits of Africa. One thinks first of the opportunities which Africa offers for investigating the

results of the transplantation of languages, which have a long history of cultural development behind them, to regions inhabited by primitive peoples. Here there are two sets of phenomena, each with its own special interest. On the one hand, we have the modification of the languages of those European peoples who have established themselves in Africa as permanent settled communities, under pressure of the new linguistic influences into contact with which they have been brought. Of these phenomena the study of Afrikaans offers perhaps the best examples to be found in the whole field of linguistics—its importance for the student of comparative philology is very far from being adequately appreciated. On the other hand, we have those cases where European languages have come to Africa as the languages not of settled communities, but of officials and others like them who are but temporarily domiciled in this continent, and leave no descendants behind them to carry on the process of evolution of distinctive forms of speech. Here the phenomena which are of interest to the student of linguistics are to be found in the wealth of deformation and adaptation which the native populations have introduced in their endeavours to speak the European languages of their rulers. Work such as has been done by Schuchardt in Negro-Portuguese and Negro-French opens up a wide area of most attractive investigation.

But the most important task in the field of African linguistics is the actual recording of the native languages of Africa, our backwardness in respect of which is a reproach to Science. Such study is, of course, important in relation to Africa itself, but of even greater significance for my present purpose is its bearing on scientific problems of wider scope. In that connection I would suggest two points. We are still only at the beginning of the study of Comparative Bantu. That in due course should lead to a knowledge of Ur-Bantu. Such a study and such a knowledge will necessarily be of importance to the comparative philologist, both because of the light shed by the study of one group of languages on the study of other groups, and also because it opens the way to the investigation of the relationship of Bantu to the other African tongues, and its place in the general scheme of the languages of the world. But of even greater interest is the study of African languages as throwing light on the inter-penetrations and interactions of primitive peoples. Language is a function of social relationship, and its study is therefore of great value for ethnological and historical investigations. May I give one instance of what I have in mind? Two millennia back South-West Arabia was the seat of the powerful commercial civilisations of the

Mineans, the Sabæans, and the Himyarites, radiating eastwards to India and south-westwards to Africa. The extent of their relationship with Africa it has hitherto been most difficult to trace, but linguistic evidence may prove to be of great value. Professor Maingard has pointed out to me that the Makaranga who live near Zimbabwe call water 'Bahri,' a word closely related in form to 'Bahr,' the 'sea' of the Arabs, although the Makaranga themselves are not a sea-board people, and that 'Shava' is their word for 'to sell or barter,' while to the Himyarites 'Saba' meant 'to travel for a commercial purpose.' Not less suggestive is the study of place-names, and while I do not suggest that I have evidence on which any conclusion can be based, I do contend that these investigations may prove to be of a most fruitful character. It would be interesting indeed to see what evidence linguistics can bring in respect of the relationship of South Africa with Madagascar, and also with Polynesia through Madagascar, where the tribe once dominant politically, the copper-coloured Hova, are ethnologically and linguistically Melanesians amid the darker-hued Sakalavas and other negroid tribes. It may even be that such studies will conjure up to our minds pictures of great migratory movements with Arab dhows and South Sea proas cleaving the waters of the Indian Ocean. Only last year a canoe constructed of wood native to South-Eastern Asia was found in Algoa Bay.

And, finally, in this survey of what Africa can give to Science I would refer, with the utmost brevity perforce, to Africa as a field, favoured as is no other, for the study of all those complicated problems which arise from the contact of races of different colours and at diverse stages of civilisation. Of those problems, ranging from the investigations of the biological factors involved in the conception of race to the practical problems of the administration of backward peoples, I need not speak. They have come to be part almost of the everyday thinking of most civilised men. What I would emphasise is that in Africa, as nowhere else, the factors which constitute these problems can be studied both in isolation and in varying degrees of complexity of inter-relationship, that in Africa we have a great laboratory in which to-day there are going on before our eyes experiments which put to the test diverse social and political theories as to the relations between white and coloured races, that in Africa there are racial problems which demand solution, and the solution of which will affect or determine the handling of similar problems throughout the world. We hear men speak of the clash of colour, and are sometimes told that Africa is the strategic point in that struggle.

I think of it rather as the continent which offers the richest opportunities to those who would investigate racial problems in the true spirit of Science, and so discover the solutions, which may yet enable that clash to be averted and the threat which it implies to our civilisation to be dispelled.

I have sought—briefly and all too inadequately—to indicate some of the lines along which Africa seems to be able to make a distinctive contribution to Science. It remains for me, yet more briefly, to speak of Africa's challenge to Science, and to seek to answer the question, What can Science give to Africa? I shall not stop to emphasise the point, that the greatness of Africa's potential contributions to Science, the key which perhaps she holds to the riddle of human origins, the intriguing vistas opened up in the study of her relationship with South America and Australasia with its suggestion of past continental continuity, that all these and more constitute a challenge to Science to actualise those potentialities. Let me seek rather to define the two-fold challenge of Africa in another way. Firstly, Africa defies Science to unravel her past. Throughout history she has ever been the continent of mystery. She was so to that pioneer of geographers, Herodotus, to whom nothing that was told him about Africa was so improbable that he declined to give it credence. She was so to the Romans, who regarded Africa as the natural home and source of what was strange and novel and unaccustomed. She was so to the navigators who did so much to break down the barrier wall between the Middle Ages and the Modern World. And though in our day the geographical mysteries of Africa have in large measure been solved, the work of the prober of her scientific secrets is only beginning. Then, secondly, Africa challenges Science to define, to determine, and to guide her future. If the great resources of this vast undeveloped continent are to be made available for humanity in our own and the succeeding generations, Science must make it possible for the man of European race to undertake that work of development, by showing him how to protect himself, his stock, and his crops against disease, by enabling him to conserve and utilise to the greatest extent the soils, the vegetation, and the water supplies of the continent, by bringing to bear the resources of modern engineering on the exploitation of its wealth, and not least by determining the lines along which white and coloured races can best live together in harmony and to their common advantage.

That is the challenge of Africa to civilisation and to Science. It is not now thrown out for the first time; it is not the first time that it will have been taken up. It is in Africa that the Greco-Roman civilisation

won some of its most glorious triumphs, in Africa that the spade of the archæologist has in our day, by uncovering great Roman towns with noble public buildings and efficient irrigation systems, provided impressive evidence of the magnitude of the achievement of Roman Imperialism. But Rome failed to conquer Africa for civilisation, and left the challenge to those who were to follow after. She failed chiefly for two reasons : the might of African barbarism and the defiant resistance of African nature. We in our day, confronted by the same challenge, still have the same enemies, hitherto victorious, to contend against. But we meet them with the advantage of having resources at our disposal which our Roman predecessors lacked. It is to use those resources effectively that Africa challenges Science.

In dealing with African barbarism we have weapons such as Rome could never dream of, and not the least valuable are those provided by the scientific investigation of the native peoples of Africa. The way to the solution of the problems presented by African barbarism is to be sought in an understanding of the character and mentality of primitive peoples, in the exploration of those regions in their social life where are to be found the factors that determine their reaction to diverse methods of administration. The study of African languages and of African Anthropology is therefore fundamental to the development of the continent. For that work Africa possesses special advantages, and one can but hope that the facilities now being built up in our South African Universities will be recognised in Britain and elsewhere, and become an important factor in the response of Science to the challenge of Africa.

Not less formidable is the conquest of African nature, for the achievement of which also we in our day are far better placed than were the Romans. It is modern Science which gives us that advantage. Three great tasks confront Science in the conquest of African nature. First, Science must make Africa safe for the white man to live in. I have spoken of the opportunities which Africa offers for the study of tropical diseases as likely to yield results of significance for Science in general. But primarily will those results be of significance for the development of Africa ? This part of the challenge of Africa is not lightly to be taken up. Africa has taken heavy toll of Science. The recent deaths in Nigeria of Stokes, Young, and Noguchi, worthy followers in the tradition of Lazear and Myers, are a reaffirmation of the gravity and insistence of that challenge. The importance for the cause of civilisation of a successful response to that challenge cannot be illustrated better than by the story

of the construction of the Panama Canal. De Lesseps attempted the task and failed. For every cubic yard of earth excavated by him a human life was sacrificed to yellow fever or malaria. It was the successful attack—some twenty years later—on the death-dealing mosquito, under the direction of General Gorgas, that made possible the completion of one of the most important engineering enterprises of modern times.

Secondly, Science must combat the foes which have to be contended with in the development of African agriculture. Africa is prodigal indeed in the production of insect and other foes to cattle and to crops. Science is already making an effective response to this part of the challenge. But there is much that remains to be done. And we shall be none the worse for the timely realisation by the politician and the administrator of the contributions which Science can make. All too often in the past settlement schemes have been undertaken and ended in disaster in areas unhealthy to man, beast, or crops, when, if the scientist had first been called in, precautions might have been taken which would have averted the calamity.

Finally, Science must harness the great resources of Africa. And here there are suggested to us all the varied contributions which the engineer can make in the work of development. Has not the Institution of Civil Engineers defined the ideal underlying all engineering activity as 'the art of directing the great sources of power in nature for the use and convenience of man'? Africa offers abundance of opportunities for the realisation of that ideal. It is not by working in isolation that the engineer will realise it, but rather by co-operation with his colleagues in other branches of Science, and by the correlation and co-ordination of the essential data which they must do so much to provide. First in the order of engineering development come the civil and mining engineers. Their tasks are the provision of facilities for communication, for health, for the conservation of agricultural assets, for the production of raw material, and for the development of mineral resources. In their train there follow, with the advent of industrial activity, the mechanical and electrical engineers. Their tasks are to make the fullest use of the revolution in ideas of transport, including transport by air, which have resulted from the perfecting of the internal combustion engine, and to secure the maximum advantage possible from cheap production and efficient distribution of electrical power. The day must come, to give a concrete instance, when the Victoria Falls, with their immense water resources, will mean much more for Africa than Niagara to-day means for America.

Later still there will be called in the services of the chemical engineer, ever engaged in problems of research to ascertain the most advantageous processes of converting raw materials into manufactured articles. In all these tasks it is the South African engineer who has, under the conditions of an undeveloped land, built up a technique and practice suitable to African requirements and showing promise of wider applicability, that we may well expect to assume a position of leadership and of inspiration. These are some of the ways in which Science can respond to the challenge of Africa.

The picture which I set out to portray I have now completed. I have tried to suggest something of the magnitude of the rewards which Africa has in store for the scientist who has the enterprise to adventure and the vision to see. I have sought also to be the medium of the challenge presented to Science by Africa's opportunities and needs. It is a vast canvas on which I have had to work. On it I have drawn but a few sketchy outlines. Yet I hope that the vision stands out clear. I hope that I have said enough to convey the power of its inspiration. Not least do I hope that you, our visitors, will play a great part, in the time that you will spend with us, in filling in some of the details of the picture, and in quickening and vitalising its message for the scientists of South Africa. It is to them chiefly that it makes its appeal. The development of Science in Africa, of Africa by Science—that is the Promised Land that beckons them. I believe that they will not be disobedient to the vision.

THE PRESIDENTIAL ADDRESS.

THE INTERNATIONAL RELATIONSHIP OF MINERALS.

BY

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A FEW years ago Members of this Association looked forward annually to a generalised statement of the results of their President's own research work in science. The rapid specialisation of science, with its consequent terminology, has, however, made it increasingly more difficult in recent years for any worker to express himself to his fellow-members.

Last year at Glasgow most of us expected that the hidden secrets of crystals would be revealed by one whose capacity for popular exposition accompanies a recognised power for extending the boundaries of science. Instead, Sir William Bragg released his store of accumulated thought on the relationship of science to craftsmanship in a way which gave each specialised worker an opportunity to adjust his sense of relativity and proportion.

If I attempted now to summarise my scattered ideas on the outstanding problems of micro-petrology, I might possibly find half-a-dozen members charitably disposed to listen, and of them perhaps one might partly agree with my theoretical speculations. We have indeed to admit that the science of petrology, which vitalised geological thought at the end of the last century, has since passed into the chrysalid stage, but, we hope, only to emerge as a more perfect imago in the near future.

Coincident with the excessive degree of specialisation which has developed with embarrassing rapidity within the present century, the problems of the Great War drew scientific workers from their laboratories and forced them to face problems of applied science of wider human interest. And the atmosphere of this great mining field¹ stirs ideas of this wider sort—ideas concerning a field of human activity which, in recent years, has affected the course of civilised evolution more profoundly

¹ The Witwatersrand.

than seems to be recognised even by students of mineral economics. This must be my excuse for inviting you to consider the special ways in which the trend of mineral exploitation since the War has placed a new meaning on our international relationships.

With knowledge of the shortcomings which were felt during the War, in variety as well as quantity of metals, it was natural immediately after to review our resources, with the object in view of obtaining security for the future. But events have since developed rapidly, both in international relationships and in mineral technology. The evolution of metallurgy during the present century, and the developments in mining on which metallurgy depend, have placed new and rigid limitations on a nation's ability to undertake and maintain a war; consequently, the control of the mineral industries may be made an insurance for peace. Let us first consider briefly how these circumstances have arisen, how each country has passed from the stage of being self-contained in variety of essential products to the most recent of all developments, the change to large-scale production that has tended to the concentration of the mineral and metal industries to certain specially favoured regions which will hold the position of dominance for several generations to come.

The names of Isis, Cybele, Demeter and Ceres seem to suggest that the ancient theologians in different lands formed the same conception of those peculiar conditions in pre-historic times which made it likely that a woman—tied for long periods to the home-cave—rather than a man, was the one who first discovered the possibility of raising grain-crops by sowing seed. Whoever it was who first made this discovery was the one who diverted the evolution of man along an entirely new branch, and so laid the foundation on which our civilisation was subsequently built—the beginning of what Rousseau called ‘*Le premier et plus respectable de tous les arts.*’

Compared with this economic application of observational science, the later inventions, which seem so important to us—explosives, printing, the steam engine—were but minor incidents in the evolution of civilised activities. Previous uncertainty regarding the supply of the products of the chase, and the dangers which were necessarily attached to the collection of berries and edible roots in the jungle, became less important to the family-man when it was found possible to raise food-supplies nearer home. This discovery was thus not one of merely material advantage; for it

necessarily led to the idea of storage, and so opened up a new mental outlook for primitive man.

But then this new possession of field-crops—the acquisition of cultivated real-estate—created fresh cares and new anxieties, which contained the germ of future political problems. In addition to the previous dangers from nomadic hunters and predatory carnivora, new troubles arose from other enemies—herbivorous animals, birds, insects, droughts and floods.

The formation of village-groups for protection, and the development later of tribal communities resulted necessarily in the radial extension of field ‘claims’—what our modern politicians, with careless disregard for geometrical terminology, now call ‘spheres of influence’—always dominated by the extending necessities of agriculture, the growing of crops for food and then, with the scarcity of skins, for textile materials.

The mineralogist and the metallurgist were perhaps before the farmer among those earliest research workers in applied science; but they were small folk, mere specialists in science. They have obtained a place of undue prominence in the minds of our modern students because of the adoption of their products for purposes of terminology in our conventional time-scale for those ages that preceded history. But this is due merely to the durability of implements as index ‘fossils,’ and is in no sense a certain indication of their political and industrial importance.

And then afterwards, long afterwards—indeed, up to historically recent times—national boundaries became extended or were fought for, but still mainly because agricultural products in some form were a necessity for the maintenance of communal life. When British traders first went to India, for instance, they extended their influence first along the navigable rivers for the trade in vegetable products which were raised on the alluvial lands around; and so British India, as we call it to-day to distinguish the administered areas from the residual native States, is now mainly agricultural. Even when the permanent settlement of Bengal was made in 1793 no one thought of reserving for the State the underlying coal which has since become so surprisingly important. It was the field, and the field only, that was considered to be of commercial and political importance.

Agricultural products, therefore, until recently dominated the political ambitions of national units. Whether, and to what extent, the possession and use of mineral resources may now modify that dominant spirit is the principal question to which I wish to invite your attention this evening.

In the evolution of man, as in the evolution of the animals that occupied the world before him, there are no sharply defined, world-wide period limits: the pre-agricultural Bushman still survives and lives the life of pre-agricultural man in this Union of South Africa. The recognition of agriculture as a leading inspiration for acquiring and holding territory has been modified occasionally by 'gold rushes' into lands previously unoccupied, but they have generally had a temporary, often a relatively small, importance. The 'gold fever' may be what our lighter species of newspaper calls 'dramatic,' but a fever is a short item in the life of a healthy man; heat-waves do not make climates. Possibly our school children are still told that Australia is noted for its goldfields, but the whole of the gold produced there since its discovery in 1851 is less in value than that of three years' output of Australian agriculture.

Even here in South Africa, which produces half the world's supply of gold, the value of the metal is still less than that of the pastoral and agricultural products. It is true that gold and diamonds introduced temporary diversions in the political expansion of South Africa, but the dominant interests of the Union are still determined by the *boer-plaas* and the *weiveld*.

The adventures of the Spanish *conquistadores* in the sixteenth century and of their enemies, the sea-roving Norse *buccaneers*, were inspired by stories of gold in El Dorado. And yet the whole of the South American output of gold, even under its modern development, is almost negligible beside the pastoral and agricultural products—wheat, maize, wool, tobacco, coffee, cocoa, sugar, meat and hides. The total production of gold for the whole continent last year was worth no more than a hundredth part of the surplus of agricultural products which the Argentine alone could spare for export. Truly there is a substantial difference between the bait and the fish, between the sprat and the mackerel.

The discovery and colonisation of a continent are not the only ways in which the lure of gold has often brought results more valuable than the metal itself. The efforts of philosophers from the time of the Alexandrian Greeks in trying to transmute the base metals into gold resulted in accumulating the raw materials with which Paracelsus laid the foundations of a new chemistry.

Metals, we know, have been used since early times for simple implements and weapons, but it was not until the industrial revolution in Great Britain that the mechanisation of industries led to any considerable development of our mineral resources, first slowly and with a limited range of products, then on a large scale and with an extended variety.

But to distinguish clearly cause from effect is not always simple. We were told at school of the remarkable series of inventors who laid the foundation of the textile industries in the north of England, and of the timely invention of the steam engine ; its application to mine pumping ; the successive construction of the steamer and the locomotive ; the production of gas from coal. But the close association of ore, fuel and flux made it possible not only to improve machinery, but to increase facilities for the transport of raw materials and their products. When Josiah Wedgwood obtained his inspiration from the remains of Greek art, then being unearthed from the ancient graves of Campania, he first turned to account the raw materials of his native county of Staffordshire, and then promoted canal and road construction to introduce the china clay from Cornwall.

It is obvious that the growth, if not with equal certainty the origin of the industrial revolution was due to the close association of suitable minerals in England. It was because non-phosphoric ores were still available that, at a later stage, Bessemer was able to give that new impetus which increased the lead of the English steel maker ; and so, when Thomas and Gilchrist came still later, with their invention of a basic process applicable to pig-iron made from phosphoric ores, their invention fell on barren soil in Britain. The new process, however, found applications elsewhere, and, instead of adding to the stability of the English steel industry, it gave the United States the very tonic they required, whilst the industrialists of Germany—where political stability had by then been established—found the opportunity of developing the enormous phosphoric ore deposits of Alsace-Lorraine, which had been borrowed from France eight years before. And so it was through the genius of Sidney Gilchrist Thomas, and his cousin, Percy Carlyle Gilchrist, that Germany was enabled in 1914 to try the fortune of war.

For the first half-century after the industrial revolution, Great Britain was able to raise its own relatively small requirements of iron as well as of the other metals that consequently came into wider use—copper, zinc, lead and tin. The rapid expansion in steel production which followed Bessemer's announcement of his invention at the Cheltenham meeting of the British Association in 1856, brought with it the necessity of going further afield for the accessory ores and for further supplies of non-phosphoric iron ores.

The next important step in metallurgical advance came in 1888, when Sir Robert Hadfield produced his special manganese-steel ; for this led to

the production of other ferro-alloys, and so extended our requirements in commercial quantities of metals which were previously of interest mainly in the laboratory—vanadium, tungsten, molybdenum, aluminium, chromium, cobalt and nickel. The adoption of alloys, especially the ferro-alloys, at the end of the last century opened up a new period in the newly established mineral era of the World's history ; for, beside the increase in the quantity of the commoner base metals which were wanted for the growing industries of Great Britain, it was necessary now to look further afield for supplies of those metals that had hitherto been regarded as rare in quantity and nominal in value.

The country in which the industrial revolution originated and gathered momentum, because of the close association of a few base metals, could no longer live on its own raw materials, and never again will do so. Even in peace time Great Britain alone consumes twice as much copper and just as much lead as the whole Empire produces. Meanwhile, developments had occurred elsewhere, notably in Germany, where political stability had been secured, and in the United States, where the Thomas-Gilchrist process also had stimulated expansion. Thus, by the beginning of the twentieth century, the industrial activities of the World had entered a new phase, which was characterised, if not yet dominated, by the necessity for minerals to maintain the expanding Arts of Peace.

From this time on no nation could be self-contained ; a new era of international dependence was inaugurated, but the extent and the significance of the change was not consciously realised by our public leaders until 1914, when it was found that the developments of peace had fundamentally changed the requirements for war. Indeed, not even the German General Staff, with all its methodical thoroughness, had formed what the tacticians call a true ' appreciation of the situation.' Two illustrations of short-sightedness on both sides are sufficient for the present argument. Up to the outbreak of war, although the wolfram deposits of South Burma were worked almost entirely by British companies, the whole of the mineral went to Germany for the manufacture of the metal, tungsten, which was an essential constituent of high-speed tool steel. Sheffield still occupied a leading place in the production of this variety of steel, but was dependent on Germany for the metal, which the Germans obtained mainly from British ore. Under the compulsion of necessity, and without consideration of commercial cost, we succeeded before the middle of 1915 in making tungsten, whilst Germany, failing to obtain an early and favourable decision in war, used up her stocks of imported ore and turned to the

Norwegian molybdenum for a substitute, until this move again was partly countered by our purchase of the Norwegian output. Germany then found that she wanted ten times more nickel than Central Europe could produce ; so she imported her supplies from the Scandinavian countries, and they being neutral, obtained nickel from another neutral country, where the Canadian ores—the World's main source—had hitherto chiefly been smelted and refined. We thus realised, not only our dependence on other lands for the essential raw minerals, but we had the mortification of finding that, through our own previous shortcomings in the metallurgical industries, we were compelled to face lethal munitions made of metal obtained from our own ores.

The political boundaries of the nations, originally delimited on considerations dominantly agricultural in origin, have now no natural relation to the distribution of their minerals, which are nevertheless essential for the maintenance of industries in peace time as well as for the requirements of defence. This circumstance, as I hope to show in the sequel, gives a special meaning to measures recently designed on supplementary lines in Europe and America for the maintenance of international peace, measures which, as I also hope to show, can succeed only if the facts of mineral distribution become recognised as a controlling feature in future international dealings.

If minerals are essential for the maintenance of our new civilisation, they are, according to the testimony of archaeology and history, worth fighting for ; and if, according to the bad habits which we have inherited from our Tertiary ancestors, they are worth fighting for, their effective control under our reformed ideas of civilisation should be made an insurance for peace. In so attempting to correlate the facts of mineral distribution with questions of public policy, there is no danger of introducing matters controversial ; everyone here must agree on two things, namely, our desire and even hope for international peace, and consequently the necessity of surveying the mineral situation as developments in technological science change the configuration of the economic world.

Since the industrial revolution in Great Britain, the increase of mechanisation and consequent consumption of metals has been accelerated with each decade. It is not necessary to quote the statistical returns available for estimating the rate of this acceleration, for it can be expressed in a single sentence which justifies the serious consideration of every political economist : during the first quarter of this present century alone, the world has exploited and consumed more of its mineral resources than

in all its previous history, back to the time when Eolithic man first shaped a flint to increase his efficiency as a hunter.

To save you from the narcotic effect of statistical statements, I will limit myself to one illustration of this generalised statement; for this special example not only illustrates the rate of general acceleration in exploitation, but introduces an important subsidiary question, namely, the way in which activity is becoming pronounced, if not substantially limited, to a group of special areas. In the year 1870 the United States produced 69,000 tons of steel; in 1880, $1\frac{1}{4}$ million tons; in 1890, $4\frac{1}{4}$ millions; in 1900, 10 millions, and in 1928, 45 millions.

Figures like these raise questions regarding the future which would take us beyond our present thesis. For the present we can assume with fair confidence that, taking the world as a whole, the depletion of natural stores is not yet alarming, although the rate of acceleration, by reason of its local variation, forces into prominence some international problems, which will influence, and if effectively tackled will facilitate, the efforts to stabilise conditions of international relations.

I have elsewhere² made estimates of the quantities of metals stored in that part of the outer film of the earth's crust which may be regarded as reasonably accessible to the miner. The actual figures in billions of tons convey no precise mental impression to us, and need not be quoted here, but certain of the outstanding conclusions have a bearing on our present line of argument.

The first feature of surprising interest to the man in the street is perhaps the relative abundance of those metals with which he is familiar in the Arts—copper, lead, tin, zinc and nickel. Nickel, in spite of its price and limited use, is twice as abundant as copper, five times as abundant as zinc, ten times as abundant as lead, and from fifty to one hundred times as abundant as tin. There are, indeed, among the so-called rare metals some which are distinctly more abundant than lead, although this is the cheapest of the lot in price, and is consumed at the rate of over a million tons a year.

And so one gets at once an indication of two important features. Firstly, the miner works only those deposits in which the metal is concentrated sufficiently to make their exploitation a profitable business; and secondly, the metalliferous ores vary greatly in the completeness with which they have been concentrated in special places to form workable

² Presidential Address, Institution of Mining and Metallurgy, *Trans.* Vol. xxxiv. 1925, p. lvii.

ore-deposits. Nickel-ore, for instance, occurs under conditions which conspicuously hinder its freedom of local concentration; and consequently the wide distribution of the metal and its relative abundance bring little comfort to those who are anxious about their supplies of a metal which jumps suddenly into importance with every rumour of war. We are safe in predicting that we shall never recover for use in the Arts any fraction of our total supplies of nickel as large as we shall of most of the others which have been mentioned. Indeed, nickel stands apart from the others; for, whilst it is important in peace time and is dangerously important during war, yet, under the present state of mining and metallurgical practice, the deposits in the world worth working for nickel can be numbered on the fingers of one hand, and nine-tenths of our supplies come from a single district in Canada.

Before discussing more precisely the significance of this and similar facts on the question of international relationships, let us consider for a moment the nature of our exploitation methods. Our reference to nickel shows that the metalliferous ores vary in their degrees of concentration, and, therefore, in their suitability for working; but, as the result of estimates made for a few common metals, we shall not be far from the average in assuming that we shall never recover more than about one-millionth of the total that lies within workable distance from the surface of our accessible dry land. And another conclusion, based on a similar group of calculations, shows that our greatest total tonnages are not contained in the rich deposits, but in those of low-grade.

It follows, therefore, that every advance in metallurgical science and in mining technology that makes it possible to work our low-grade ores adds appreciably to the actuarial value of civilisation; for our mineral resources can be worked once and once only in the history of the World, and when our supplies of metalliferous ores approach exhaustion, civilisation such as we have now developed during the last century must come to an end. When a miner raises a supply of ore in concentrated form for the metallurgist, he damages, and so places beyond reach for ever, far larger quantities of residual ore than he makes available for use. When a metallurgist takes over the product of the miner and separates the refined metal for use in the Arts, he also incurs serious losses, although not to the same extent. There are thus before both the miner and the metallurgist opportunities for extending the actuarial value of civilisation; and because the cost of labour is the principal constituent in the total bill, and has recently swamped contemporaneous advances in technology, the

gradual elimination of manual labour by mechanisation is obviously the most profitable line of research.

But mechanisation carries with it in general a tendency to limit operations to the larger deposits, with the concurrent neglect of those propositions which are widely scattered over the earth, and, though individually small, represent in the aggregate a serious section of our limited resources. And so our operations in mining, with the family of industries dependent on minerals, tend more and more to be restricted to a few special regions, where work can be done on a large scale.

So now, with this thumb-nail sketch of the way in which the new mineral era is developing, we are free to examine more closely the influence which this change in the configuration of the industrial world is likely to have on international relationships.

In the first place, it becomes obvious that no single country, not even the United States, is self-contained, whether for the requirements of peace or for the necessities of war. Not even the more scattered sections of the Earth that are politically united to form the British Empire contain the full variety of those minerals that are the essential raw materials of our established activities.* Between them these two—the British Empire and the United States—produce over two-thirds of the 2,000 million tons of mineral that the world now consumes annually. Each of them has more than it wants of some minerals; but, in order to obtain its own requirements at economic rates, each finds it necessary to sell its surplus output to other nations. Each produces less than it wants of some minerals, and so must obtain supplies from other nations to keep its industries alive. Each of them is practically devoid of a few but not always the same

* For purposes of reference I give a list of minerals, showing how the resources of the British Empire, so far as our present information goes, can be relied on. This list has been kindly revised by Mr. T. Crook of the Imperial Institute.

1. *Those for which the World now depends mainly on the Empire* :—Asbestos, china clay, chromite, diamonds, gold, mica, monazite, nickel and strontium.

2. *Those of which we have enough and to spare* :—Arsenic, cadmium, cobalt, coal fluorspar, fuller's earth, graphite, gypsum, lead, manganese, salt, silver, tin and zinc.

3. *Those in which we could be self-contained if necessary* :—Bauxite, barium minerals, felspar, iron ore, magnesite, molybdenum, platinum, talc, tungsten and vanadium.

4. *Those for which we are now dependent on outside sources* :—Antimony, bismuth, borates, copper, petroleum, phosphates, potash, pyrites, quicksilver, sulphur and radium.

A corresponding list for the United States was prepared in 1925 by a Committee under the chairmanship of Prof. C. K. Leith, and published under the joint authority of the two Mining and Metallurgical Institutions in New York.

minerals, which, though relatively small in quantity, are none the less essential links in the chain of industrial operations. Even if these two could 'pool' their resources they would still be compelled to obtain from other nations the residual few. For it is important to remember that, unlike organic substance, it is not possible to make synthetic metals, and it never will be; it is not even possible to make artificial substitutes for many essential minerals that are used as such and not merely for their metallic constituents. There is no other mineral and no artificial substance for instance that can combine the qualities which give to the mineral mica its position of importance in the Arts—its fissility in thin sheets, its transparency to light and opacity to heat rays, its stability at high temperatures, its toughness and the degree of its insulating properties. There will never be a synthetic mica.

Thus the international exchange of minerals is an inevitable consequence of our new civilisation; and the cry for freedom of movement, for the 'open door' and for equal opportunity for development comes into conflict with the unqualified formula of 'self-determination.' Whatever may have been possible before the industrial revolution, when the mineral industry merely contributed to the simple wants of agriculture, when most national units were self-contained, the formula of 'self-determination' has come too late in the World's history to do good without a more than consequent amount of harm. We cannot even live now without the free interchange of our minerals for those of other nations; in the name of civilisation we dare not go to war.

There is one more group of fundamental data to recall before we are in a position to point the practical lessons which follow from the newly established and prospective mineral situation. I have already referred to the way in which economic considerations tend, through large-scale production, to restrict operations to a limited number of specially favoured areas. There was a time within my memory when the primitive *lohar*, a survival of the aboriginal inhabitants of India, could be found in every province, nearly every district. He collected the granular mineral from the weathered outcrops of relatively lean iron-ore bodies, and, by using charcoal as a fuel, turned out blooms of malleable iron in a miniature clay furnace, using a pair of goat skins to produce the necessary blast. These primitive workers also produced small ingots of steel by the carbonisation of wrought iron in clay crucibles many centuries before the same process made Sheffield famous.

But with the large-scale production of steel in western countries,

attended by the opening of the Suez Canal, cheaper transport by steamers and the spread of railways from the coast of India, the *lohar* has been exterminated from all but the most remote parts of the country. His history is similar to that of other workers; the small ore-bodies that he used are of no interest to the modern iron-master, and one result therefore of the modern movement is the neglect of a large fraction of our total resources. We are discussing, however, what is actually happening, not what we think should be a less wasteful course of evolution; natural evolution, like 'trial and error' methods, is always wasteful.

Primitive workers in various lands have opened up to relatively shallow depths rich but small deposits of other ores, and in Eastern countries especially, where forms of civilisation extend far back into history, the numerous and widespread 'old workings' have given rise to travellers' impressions of great mineral wealth. But low-grade deposits that the ancient miner could not utilise are now opened up by mechanical methods on a large scale; and, on the other hand, what satisfied the primitive metallurgist in abundance would be of little use to the modern furnace.

We have now to revalue the tales of travellers which have had a dangerous influence on those who have directed the course of international competition; we have to strike out of consideration the integers of the primitive worker to whom a great tonnage would form a mere decimal point in the modern unit; we have to realise that our mid-Victorian standards of metal production are gone for ever, and that the comforting after-war formula of 'back to normal' is merely a hypnotic drug to conceal the uncomfortable, one might say regrettable, dynamic conditions which have since developed at a speed that is not sufficiently recognised within our Empire.

It is now misleading to speak of the wide distribution of minerals within a country as we could have done some fifteen years ago; we must now rule out the smaller deposits, and so form a new picture composed of those concentrations that are on a scale sufficient to support modern metallurgical units.

For this reason it is necessary to review afresh the resources of the undeveloped Far East, which has for many years been regarded as a menace to Western industrial dominance. The vague general notion that mineral deposits are evenly distributed throughout the Earth's crust has fed the impression that the development of China, which is much larger than the United States, may yet shift the centre of industrial gravity when

her great population becomes awakened and organised by western technical science.

It is true that the people of the East are rapidly adopting the methods and using the mechanical facilities of western nations—railways, telegraphs, power factories, steel ships and other metal-consuming devices ; but the critical investigations made by mining geologists, especially since the war, tend, with a striking degree of unanimity towards recognising the remarkable circumstances that China, as well as other countries of the Far East, is deficient in those essential deposits of minerals on which our mechanised form of civilisation is based.⁴

When China was still an unknown land it was possible for after-dinner speakers to impress non-critical hearers by talk of the 'yellow peril' and the 'challenge of Asia'; but these expressions have been used without thought of the circumstances that natural resources in minerals now sets a rigid limit to power, whether industrial or military. We have known for some time of the natural limitations of India, of Japan and of smaller political units in the East ; but until very recently we have had insufficiently precise data for estimating the quantitative value of the terms 'vast' and 'unlimited' which have been so often applied to China. Assuming that China may yet become a homogeneous national unit, or even assuming that her resources may become developed by Japanese energy, there is very little doubt now that, as an industrial area, the country is deficient in those minerals that form the essential basework of the modern form that civilisation has definitely taken.

And the obvious limit in development, as defined by local natural resources, can be extended only to a limited degree by the importation of raw materials from other areas ; for a country can buy metals only by the exchange of other products ; its buying powers are limited by its selling powers. Abundant cheap labour, assisted by a semi-tropical climate, can produce an exportable surplus of food stuffs only in limited parts of the Far East ; even the so-called luxury products, which to our early navigators formed the inspiration of what we call geographical research, are now obtained elsewhere, and some are being replaced by artificial products evolved from the chemical laboratory.

Exploratory work by mining geologists tends more and more to show that the essential mineral products are far from evenly distributed over

⁴ A comprehensive study of this question with bibliography has recently been published by a competent and judicial authority, H. Foster Bain : 'Ores and Industry in the Far East,' 1927.

the land areas of the world. Western Europe and North America have an undue share of those deposits that can be worked on a large scale, and it is the large-scale movement that marks the specialised character of the new industrialism. Anglo-Saxon character would have found limited scope for its energy but for the fact that nine-tenths of the coal, two-thirds of the copper and as much as 98 per cent. of the iron-ore consumed by the world come from the countries that border the North Atlantic. Dr. Wegener might like to add this fact to the data on which he has based his theory of drifting continental fragments.

The industrial revolution, which began in Great Britain, has always been recognised as a dominant phase in western civilisation, but it is now assuming a new character. It spread first to the western countries of Europe, and developed there because of the favourable conditions of mineral resources, but the force of the movement faded out towards the Slavic East and the Latin South; the mechanical industries of Italy are based on imported scrap. When the new industries became transplanted west of the Atlantic the natural conditions which originally favoured Great Britain were found to be reproduced on a larger scale.

Thus, in these two main areas, separated by the Atlantic Ocean, a family of industries based on mineral resources has arisen to dominate the world; for no similar area, so far as our geological information tends to show, seems to combine the essential features in any other part of the world. Other parts of the world will continue to supply minor accessories; and the isolated basic industries associated with coal and iron will supply local needs on a relatively small scale. But political control, which follows industrial dominance, must lie with the countries that border the North Atlantic.

It is only in this region that there is any approach to the state of being self-contained. And yet since the war there has arisen, first in Europe and then by imitation in Asia, a degree of national exclusiveness more pronounced than any which marked international relations before 1914. Each small political unit has become vaguely conscious of the value of minerals, and has shown a tendency to conserve its resources for national exploitation on the assumption that they add appreciably to military security.

There is, however, no such thing now as equality of nations in mineral resources; 'self-determination' and the 'closed door' are misleading guides to the smaller nations. Political control may hamper, but cannot stem, the current of the new industrialisation; commercial and industrial

integrations are stretching across political boundary-lines ; and the demand for the interchange of mineral products will be satisfied in spite of fiscal barriers.

It would have been a shock to our members if, before the war, political problems were discussed from this Chair, and party politics may always be inconsistent with the mental products of culture. But the results of science and technology now limit the effects of national ambitions, and therefore dominate the international political atmosphere for good or evil. One is justified always in suggesting non-controversial measures that tend to good ; and this it is proposed to do very briefly as the direct suggestion of the new configuration of the mining and metallurgical world.

The League of Nations has accomplished a large measure of international understanding in questions of social value ; its influence in forestalling possible causes of war has raised new hopes ; but fortunately, so far, it has not been compelled to use any such instrument of force as a blockade, and any such measure that clashed with the vital economic considerations of first-class powers would probably cause stresses well beyond its elastic limits. The more recent and simpler pact of Paris associated with the name of Mr. F. B. Kellogg wants equally an ultimate instrument for its practical enforcement.

It was with this ultimate object in mind that the outline of my argument was drafted after the Glasgow meeting last year ; but I am glad to find that my views have since been expressed independently. Senator Capper, of Kansas, in February last submitted a resolution to the American Legislature recognising this shortcoming of the simple treaty, and proposing to supplement its moral obligations by a corollary which, if passed, will empower the Government on behalf of the United States to refuse munitions to any nation that breaks the multilateral treaty for the renunciation of war.

Senator Capper's resolution, however, still leaves unsolved a residual problem of practical importance. Those of us who had the painful duty of deciding between civil and military necessities in the Great War, know well that there is now but little real difference between the materials required to maintain an army on a war footing and those that are essential to the necessary activities of the civilian population ; *materials* essential for one purpose can be converted to *articles* required for the other. Thus, if Senator Capper's resolution be adopted by those who have signed the Kellogg Treaty, either sympathy for the civil population would be stirred, or the armies would be still supplied with many essential munitions : the

definition of 'conditional contraband' would still remain as a cause for international friction.

A formula, still simpler but equally effective, is indicated by this review of the new situation arising from the essential use of minerals. It is suggested, therefore, as an amendment to Senator Capper's resolution, that the simple words 'mineral products' be substituted for 'arms, munitions, implements of war or other articles for use in war.'

The only two nations that can fight for long on their own natural resources are the British Empire and the United States. If they agree in refusing to export mineral products to those countries that infringe the Kellogg Pact, no war can last very long. As our friends across the Atlantic have recently learnt, it is easier to stop exports than to prevent imports : the Customs' officer is more effective, less expensive and far less dangerous than a blockading fleet.

The confederation of American States has the advantage of forming a compact geographical unit, without inter-State fiscal barriers to hamper the interchange of mineral products. The British Empire, in the words of Principal Nicholas Murray Butler, 'has passed by natural and splendid evolution into the British Commonwealth of Nations'; it is composed of geographically scattered and independent political units, among which freedom of interchange, with due regard to local interests, can be effected safely only by more complete knowledge of our resources. Next year the Empire Congress of Mining and Metallurgy will meet in this city to discuss the proposition which I submitted to it at Montreal in 1927; and this Address must be regarded, therefore, as an introduction to a movement which one hopes will supply the necessary data, and so facilitate a working agreement between the two great Mineral Powers that alone have the avowed desire and the ability to ensure the peace of the world.

SOME PROBLEMS OF COSMICAL PHYSICS, SOLVED AND UNSOLVED.

ADDRESS BY
LORD RAYLEIGH, F.R.S.,
PRESIDENT OF THE SECTION.

OF the activities of our section, the Cape has perhaps been more identified with astronomy than with any other branch. In the middle of the eighteenth century, when exact astronomy of the southern hemisphere may be considered to have begun, there were few, if any, other places in a considerable southern latitude where an astronomer could work in safety with the necessary help of trained artisans. This tradition worthily begins with Lacaille (1750–1751). Other landmarks were the foundation of the Cape Observatory (1821), the expedition of Sir John Herschel (1833–1838), and the forceful and energetic career of Sir David Gill, who was the life and soul of our organisation on its visit to South Africa in 1905. Shortly afterwards he retired, and I then had the privilege of friendship with him in London. Indeed I have taken these few facts and dates from the copy of his ‘History of the Cape Observatory,’ which he gave me very shortly before his death. Although past his prime at the time I knew him, he was still vigorous and keenly interested in scientific developments; though, if one brought anything new to his notice, a severe cross-examination as to the validity of the evidence had to be faced.

It is partly on account of this association of South Africa with astronomy that I have chosen to lean as far towards this direction as I feel able, and to pass in review some subjects lying on the border-line between astronomy and physics.

After the first period of success in identifying the origin of the spectral lines of the sun and stars with terrestrial materials certain outstanding cases remained which were obviously important, but in which the identification could not readily be made.

The first of these cases to yield was that of helium, which was unravelled while some of the pioneers in astronomical spectroscopy were still active. Although in my youth I was privileged to see the discovery of helium at close quarters, I shall not go back so far. When we hear of the gas being used in millions of cubic feet for inflating large airships, we have to realise that its discovery is an old story.

Kindred to the hypothesis of helium, so triumphantly vindicated by terrestrial experience, were the hypotheses of nebium, geocoronium and coronium. The problems epitomised by the two former words have now been solved, though the solution has taken quite a different turn from what was expected by the older generation of astrophysicists.

THE NEBULAR SPECTRUM.

In the nebulae are spectrum lines which have never been observed terrestrially. These are not faint members of otherwise complex spectra, such, for instance, as we have in nearly all remaining unidentified lines of the solar spectrum, but they stand out, bold and challenging, on a dark background, presenting a puzzle that was the more intriguing from its apparent simplicity. According to spectroscopic experience, now made precise and rational, simple spectra are due to light elements. This, taken with the fact that lines known to be due to hydrogen and helium accompanied the nebular lines, strongly suggested that they too were due to light elements of the class which terrestrially are known as permanent gases. But the fact remained that no one had succeeded in observing them in the laboratory, and as time went on the originally convenient resource of relegating them to an unknown element had become less convenient. For the scheme of the elements became definite, and there was no room in it for new light elements. This was one of the many cases in science where the method of frontal attack has been exhausted in vain. More systematic knowledge of spectra in general, and of the spectra of the light elements in particular, was wanted before the question could be resolved.

The clue was afforded by the circumstance that important nebular lines occur in pairs, obviously associated by their closeness and their constant relative intensity in different nebulae and in different parts of the same nebula. The consideration of such pairs or multiplets has more than once proved an advantageous point of attack on spectroscopic problems. It was in this way that Hartley, examining the diffuse triplets of magnesium, first established the constancy of frequency intervals, thus suggesting for the first time that addition and subtraction of frequencies was the proper method of analysing spectra—an idea which appeared at that time sufficiently paradoxical. Again, the recognition of the frequency intervals of multiplets afforded the clue by which complex spectra such as manganese and iron were first unravelled.

It is found then that the frequency difference of the green pair of lines originally discovered by Huggins, and known as N_1 and N_2 is 193 waves per centimetre. I. S. Bowen, to whom we owe the final elucidation of this enigma, sought for an equal interval in the spectrum of doubly ionised oxygen which he was analysing and found it in the interval between the low-lying levels designated as I^3P_2 and I^3P_1 .

This is hardly enough in itself to establish the suggested origin; to do that it is necessary to fix, not only the interval between the nebular lines, but their position as well. The lines were attributed to intercombination between one singlet upper level and two lower levels belonging to a triplet, the third being excluded by the rule of inner quantum numbers. To fix the differences of the terms concerned it was necessary to connect the singlet and triplet levels by an intercombination line observed in the laboratory spectrum of doubly ionised oxygen. This was done by A. Fowler, who, combining Bowen's laboratory data with his own, was able to get a fairly satisfactory check on the observed position of the nebular pair. Practically no doubt remains, in view of the fact that other less well-known nebular

lines can be similarly explained as due to singly ionised nitrogen and singly ionised oxygen.

The identification of these lines was made by ignoring so far as convenient the rules of the quantum theory which had been evolved from laboratory experience, and given some theoretical basis by Bohr and his followers. These rules forbid certain lines which might occur according to the combination principle. When a state of excitation of the atom is such that it cannot directly pass to a lower state without breaking one of these rules, that state is called metastable; and this is the case which we have in the nebular lines. I shall return presently to the consideration of metastable states and 'forbidden' lines.

THE AURORAL SPECTRUM.

The next cosmical problem I wish to refer to is the long outstanding one of the green line of the aurora. This was first seen by A. J. Ångström at Upsala in 1868, and he recorded the observation in one of the supplementary notes at the end of his great paper in which an extensive scale of wave-lengths for the solar spectrum was first established. In this case the enigmatic line is even more isolated than in the case of the nebulæ, since, except in the case of unusually bright auroras, one can see nothing else in the spectrum at all. For some years I took every available opportunity of looking at this spectrum, and never did so without a deep sense of mystery. The origin of the line was not in this case in the depths of space, but in our own atmosphere at the distance of a short railway journey from the observer. Yet an apparently exhaustive study of the spectra to be obtained from terrestrial gases by the combined efforts of very many experimenters gave no clue to its origin.

As is well known, the clue was eventually found by McLennan, who was able to produce the line by heavy electric discharges in a mixture of oxygen and helium, or, better, oxygen and argon. Oxygen is essential, and there is now no doubt that the aurora line is an oxygen line, but the function of the inert gas is not very clear, though various more or less plausible guesses may be made. To have established that the line is due to oxygen is an immense step forward. There is, however, yet more to be done, for we do not know how to get the green line alone or with only the negative nitrogen bands as we see it in the sky. In the artificial spectrum the ordinary oxygen lines and the lines of the inert gas, helium or argon as the case may be, are conspicuous.

The wave-length of the auroral line could not be foreseen or calculated from our present knowledge of the arc spectrum of oxygen. In this case we have only a single line to deal with, and are thus without the invaluable clue afforded in the case of the nebulæ by the frequency separations of a doublet or triplet. There is, however, no difficulty in finding a conjectural place for it in the scheme of the oxygen arc spectrum as given by Hund's theory. This theory, which may be regarded as a generalisation of all our knowledge of line spectra, affords a kind of frame into which we may confidently hope to fit new empirical knowledge as it accumulates.

McLennan, arguing from the fact that nitrogen bands do not appear in the spectrum of the night sky, which, however, shows the green line,

takes the excitation potential as less than 11·5 volts. This condition excludes very many possibilities. Indeed, if we are to be bound by the selection rules, it excludes *all* the possibilities. So, with the example of the nebulae before him, McLennan waives these rules, and assigns the green line to a transition from one or other of the low-lying metastable states which the theory indicates.

The lowest state of all should be a triplet, and owing to the absence of companions to the green line this may very probably be excluded.

If so, only one alternative remains, and the successful determination of the Zeeman effect carried out in McLennan's laboratory is in harmony with the choice so arrived at. An independent investigation by L. H. Sommer, published immediately afterwards, covered exactly the same ground, and led him to the same choice. This is satisfactory so far, but the position will be much strengthened and consolidated when we have an independent determination of the levels in question, giving the means of calculating a theoretical wave-length for comparison with that observed. To do this will require a fuller survey of the Schumann region of the arc spectrum than has yet been made. For the aurora line we have the experimental production from oxygen but not the numerical spectroscopic relation. For the nebular lines our position is exactly the reverse.

The origin of the green auroral line has thus been definitely cleared up, at all events in so far that it is attributable to the arc spectrum of oxygen. There are, however, other features of the auroral spectrum which are still obscure. I will limit myself to discussion of one of them—the red line of the aurora. Red auroras are comparatively rare, and when they do occur the distribution of colour presents very curious features. In some cases the ends of the streamers are tipped with red, while the greater part of the length is green. The only reddish aurora which I have been privileged to observe at my home in the south of England (May 14, 1921) was of a different character, the colour ranging rapidly through various shades of purple. The light was distributed in irregular patches high up near the zenith, though predominantly in the north. At the same time its position was highly unstable, and the general impression produced was reminiscent of high potential discharges in highly exhausted vacuum tubes. Vegard has described cases where the whole sky suddenly turned crimson. He has obtained good small-scale spectrograms of the red line, which give the position as $\lambda 6322$, which, however, is subject to a probable error of at least $\pm 1\text{\AA}$. A determination by V. M. Slipher of the Lowell Observatory gave $\lambda 6320$.

So far as can be judged from the evidence available, no pair of the low-lying levels of the oxygen arc scheme which McLennan has discussed in connection with the aurora are suitably placed to yield this red line by combination. We naturally turn to the consideration of nitrogen spectra, which, as is well known, are represented in the blue and violet regions of the auroral spectrum.

I described in 1922 a spectrum in which one of the first positive bands of nitrogen $\lambda 6323$ was very much intensified relative to the neighbouring red bands, which ordinarily are of comparable brightness. This spectrum was produced by adding a large excess of helium to the nitrogen afterglow, and the source had a visual red colour dominated by this band. In

describing this work it was suggested as a possibility that this was the origin of the red auroral line, and somewhat similar ideas have been revived by McLennan in his recent Bakerian lecture. But there are difficulties to be met. Photographically two yellow nitrogen bands come in with intensity equal or superior to the red one, and these have no counterpart in auroral spectra. Moreover, the wave-length data for the red auroral line are far from being accurate enough for an identification depending on a single coincidence only. One of the most urgent problems in auroral work is an adequate wave-length determination of this red line from a large-scale spectrogram.

CORONIUM.

A problem which has generally been classed with those we have been discussing is that of the lines in the sun's corona, attributed to a hypothetical coronium. In the light of our present knowledge it is not probable, perhaps we may say not possible, that an unknown element coronium exists. Attempts have not been wanting to identify these lines with known elements. The latest is by Freeman, working in the Ryerson Laboratory of Chicago, who seeks to attribute the lines to argon. He thinks, for instance, that the strong visual green line, from which the conception of coronium arose, may result from two different transitions in the argon atom, being in reality double. One of his proposed transitions would give the fifth line of a possible series, and the other the ninth member of an actual series. But none of the earlier members of either of these series are seen in the corona, and this seems fatal to the identification proposed. We could not assign an observed line at $\lambda 3771$ as H_i (H iota) if H , H_β , and H_γ , and the other earlier members of the series were missing, yet this would be an analogous case.

I think we must consider the origin of the strong lines of the corona as an unsolved problem. The possibility of their being in reality heads of molecular bands must be kept in view.

EXCITATION OF THE VARIOUS SPECTRA.

We have discussed these cosmical spectra so far chiefly from the standpoint of the spectroscopist. It will now be of interest to consider the probable mode of excitation of some of them.

Let us consider first the polar aurora ; - this, as is well known, is closely bound up with exceptional conditions of magnetic disturbance, and these in turn are conditioned by solar influence. As regards the nature of this influence, the theory of Birkeland, elaborated by Störmer, still holds the field. The sun was regarded by them as emitting localised streams of electrically-charged particles from limited areas of its surface.

The unrivalled advantages of this theory are that it allows the solar action to be emitted in a highly specialised direction, thus accounting for the sudden commencements of magnetic storms all over the globe, and their tendency to recur after the twenty-seven days of a solar rotation have passed : and further, that by the earth's magnetic field the action can be got round to the night side of the earth. But this theory in its original simplicity has required a good deal of patching, and it is difficult

to feel much satisfaction with the special *ad hoc* hypotheses which have had to be introduced into it.

A stream of particles with a charge of one sign only is open to the criticism, first put forward by Schuster, that the stream will dissipate itself by electrostatic repulsion, and loses the hard outline which is one of the most essential features. Lindemann has proposed to get over the difficulty by making the stream neutral on the whole, still consisting, however, of charged particles of both signs. Here, however, we lose too much of the magnetic flexibility of the stream. Chapman proposes to retain a slight excess of charge of one sign, and in this way is able to arrive at a tolerable compromise. But one feels that more experimental guidance is badly needed before we can venture with confidence into these theoretically dark regions. The search for direct evidence might not seem at first sight very hopeful, but not long ago a sensational suggestion was made by Störmer. His attention was drawn by Hals to echoes heard after short-wave (131 metres) wireless signals sent out from Eindhoven in Holland. These echoes have been found by Störmer and Hals at long intervals up to as much as fifteen seconds after the original reception.

Now, if we bear in mind that with the velocity of light the longest terrestrial distances only give intervals about $\frac{1}{7}$ of a second, it seems inevitable that some extra-terrestrial reflector should be looked for. Störmer finds this in the corpuscular stream as bent round by the earth's magnetic force. Though the boldness of the idea is staggering, it is difficult to suggest any alternative view. Störmer states that 'the variability of the phenomenon indicated by the observations agrees well with the corresponding variability of aurora and the magnetic registrations.'

T. L. Eckersley has made an observation on electrical disturbances of natural origin which he interprets as analogous to Störmer's. A click is heard in a telephone attached to a large aerial, which is followed at an interval of about three seconds by a 'whistler' or musical note of short duration. Further whistlers follow at intervals of 3·8 seconds, each more drawn out than the previous. The musical notes are regarded as due to the spreading action of a dispersive medium on an electrical impulse. It is only at times of magnetic storm that these phenomena are frequent.

Further development of observations of this kind will be awaited with keen interest.

To return to the nebular spectrum: although the main problem has been cleared up in the way described, it would still be an important step to imitate the spectrum in the laboratory, not so much to confirm the origin of the lines as to get direct information about the conditions under which they may be excited. No success has yet been obtained in this direction, but it is fairly clear how the attempt should be made. We must have conditions capable of exciting the lines of doubly ionised oxygen and attempt to work in a large volume at high rarefaction.

A large volume and high rarefaction (rarity of collisions) is suggested by the nebular conditions, and was plausibly held by Bowen to be an essential. It must be allowed, however, that such experimental evidence as we have at present on passage downwards from metastable states does not definitely point in this direction.

In such attempts what Darwin called 'fool experiments' and what prospectors for oil call 'wild catting,' are not to be discouraged. Indeed, many of the most fruitful discoveries are really made in this way. The logic is put in afterwards. That is what happened in the case of the 3-electrode thermionic valve.

Thanks to the work of Wright, Hubble and others, the source of excitation in the bright line nebulae no longer appears inexplicable. We have the cardinal fact that in nearly all cases stars of early type, capable of affording radiations of high frequency, are involved in the nebulae. The two or three apparent exceptions, though deserving of the closest scrutiny, do not at present seem to have enough weight to upset a generalisation which rests on a great number of cases. It is true that we cannot observe these short waves, the maximum of intensity in the spectrum being hidden from our view by the layer of ozone overhead, which I shall say more of presently. But we can confidently infer their existence by extrapolating from what we can see, and correcting for what we know of atmospheric absorption. The cases of some of the central nuclei of the planetary nebulae are specially satisfying from the definite relation of the star to the nebula and the adequate character of the star itself. W. H. Wright, writing in 1918, before these views had emerged, and without any thesis to maintain, expressed himself as follows :—¹

'I cannot but believe that this wonderful richness in ultraviolet light which gives the spectra of nebular nuclei their characteristic appearance, in spite of the great difference which they exhibit in the matter of bright bands, is the dominating peculiarity which must be regarded as the distinguishing mark of this group of objects.'

It has been suggested that the general penetrating cosmic radiation of which we have heard so much of late stimulates the nebular spectrum ; but upon the facts available this hypothesis hardly seems necessary or helpful.

THE DARK PATCHES IN THE NEBULÆ.

There is another aspect of the diffuse galactic nebulae which remains obscure in more senses than one. It is seen to special advantage in such objects as the 'trifid' nebula in Sagittarius. Dark regions are, as it were, interlarded with the bright ones in a way which strongly suggests that we have to do with complementary aspects of the same phenomenon somewhat in the same way that, for instance, the emission of a fluorescent body is connected with its absorption. Yet it is very difficult to pursue this line of thought into satisfactory detail. The opacity is quite unrelated to the emission, and indeed it presents the baffling peculiarity of having no peculiarity. For apparently every part of the spectrum of the stars lying beyond is obscured in the same ratio. Experimenters in the field of optics know how difficult it is to secure a result of this kind in the laboratory, particularly when the ultraviolet spectrum has to be included.

Even fairly opaque gases like iodine vapour which are at our disposal show markedly selective absorption, and in terrestrial experiment recourse is usually had to the partial action of a solid obstruction such as a spinning

¹ Lick Observatory, vol. xiii, p. 252, 1918.

sector or a wire gauze not seen in focus. The astronomical equivalent of these devices is a swarm of meteorites, and it may be necessary to invoke their aid, but the rare gaseous atmosphere required to give the line spectrum of hydrogen, helium, nitrogen and oxygen cannot be considered to blend harmoniously with a swarm of meteorites or to have anything like a complementary relation to it; and it is particularly difficult to understand from this point of view how it can come about that the bright nebular lines are often seen on a profoundly dark background almost or quite free from continuous spectrum.

COMETS.

A kindred problem is that of the luminosity of comets. This has been discussed by Zanstra in a recent paper. [M.N., Dec., 1928]. He takes the view that the Swan bands of carbon are resonance bands excited by light from the sun in the visual spectrum, the gases being at an ordinary temperature such as prevails at the earth's surface. If these are really the conditions, the problem of imitating the comet seems ideally easy from the laboratory point of view. The Swan spectrum should appear in absorption of suitable carbonaceous gases, contained in a vessel at the ordinary temperature; and it should be observable in lateral emission. I cannot help thinking that if nothing more than this was necessary, the thing would have been done before now. In the case of the D line sodium, treated by Zanstra as quite analogous, it has of course been done long ago in the phenomenon described by R. W. Wood, and called resonance radiation.

METASTABLE STATES.

In discussing the nebular and auroral spectra, we encountered the idea of 'metastable states.' At present this conception is not in a very satisfactory condition. The original idea was of a state which did not allow of direct transition by emission of radiation to the stable ordinary state. Let us compare the level of the atom to the stories of a building and the optical electron to a man inside the building. The ordinary state of the atom is represented by the man being on the ground floor, and the metastable state by placing him on the first floor. But the internal architecture of our building must be pictured as peculiar. A staircase connects the first floor with the second floor, and another staircase connects the second floor with the ground floor: but there is no connection between the first floor and the ground floor except by going up higher and coming down again.

Such, I say, was the original conception, but facts which have since come to light require some revision of it.

In the nebulae the electron manages somehow to escape from its prison-house, and descend to the level below not by the legitimate route of going upstairs and down again, but by illicitly breaking through the floor, contrary to the rules of the establishment.

Abandoning the metaphor, and the attempt to use popular language, the selection rule which forbids transitions not involving a change in the azimuthal quantum number is violated in all such cases. The inner quantum number rule, which requires that the inner quantum number should not change from 2 to 0 or from 0 to 0 is also violated in one class of cases, and rather meticulously observed in another.

This rule permits only the pair of green nebular lines in doubly ionised oxygen which we have discussed; and in deference to it only two are observed, instead of the three which apart from this might have been expected from the triplet ground state.

Yet we find the blue singlet line $\lambda 4363$ of this ion violating the same rule, and the same applies to the analogous case of the aurora line, if we adopt McLennan's view of its position in the scheme of the arc spectrum.

In the case of the mercury spectrum, which lends itself well to experimental observation and of which much detail is known, we have laboratory examples of the violation of this rule, as originally shown by experiments of Takamine, Fukuda and other Japanese physicists. The lines were originally obtained under conditions where a strong electric field was acting, and this was sometimes urged in mitigation for breaking the rule. Again, the lines were of low intensity, and this too was thought to be a partial excuse.

Whatever might have been thought of these apologies originally their irrelevance was, I think, clearly shown in some experiments of my own, in which one of the 'forbidden' mercury lines was obtained as the second strongest line in the entire mercury emission spectrum, in the vapour passing through a discharge, but altogether away from the region in which the discharge itself was taking place, and consequently in the absence of an extraneous electric field.

In another experiment I was able to obtain the other forbidden line as an absorption line in unexcited mercury vapour, and thus apparently in the absence of any disturbing conditions. In this experiment the quantity of vapour used was very large, about ten million times the amount required to bring out the resonance line of mercury in absorption. The probability of the transition thus indicated is very low, and for the other forbidden line it is apparently still lower. But for all that, as we have seen, this forbidden line can be got in considerable intensity in emission. The necessary condition in the mercury experiments appears to be a large accumulation of mercury atoms in the relevant metastable state, so that even with a low probability of transition for the individual excited atom a considerable number of transitions occur.

It has even been proposed to define a metastable state as one with a low probability of transition. This takes us far from the original conception, and makes 'metastability' merely a question of degree. Some recent results which I hope to bring before the section at a later stage in our proceedings seem to indicate that even the normal excited state may possibly persist for a much longer time than has hitherto been supposed. If this conclusion is accepted, a far-reaching revision of our present notions may become necessary. The general softening of outline in our picture of atomic events resulting from the substitution of wave groups for particles seems likely to afford what is required, and to allow the occasional transition downwards from a metastable state.

OZONE.

The case of the nebular spectrum affords an illustration of how spectroscopic theory, working on laboratory data gained in the remote ultraviolet region, enables us to some extent to turn the difficulties which arise from

our inability to examine this region in celestial spectra. The veil of atmospheric ozone overhead cuts off the spectra of the sun and stars and thus hides much of the ultraviolet, constituting a great obstacle to astrophysical research. On the other side of the account we may remember that it protects our persons from the harmful ultraviolet rays, and that without it we might not be here to conduct research at all. It has been suggested by Cario, R. W. Wood and others that on the view that atmospheric ozone is generated by the absorption of short-wave lengths in the sun's spectrum, it may be absent in the Arctic during the polar night. This possibility has been put to the test by Rosseland, but with negative results. It is doubtful whether his station was far enough away from the sunlight to make his result absolutely final. But other omens are unfavourable. Thus Chalonge has found that the amount of ozone present in the night (using the moon as a source) is notably more than by day; and Dobson, Harrison and Lawrence have found that when the meteorological conditions are such as to bring air from the Arctic, the ozone content goes up, and that this is particularly marked in spring, when the Arctic has been without sunlight for months. The point is, however, of great interest in itself, and makes the question acute of how the ozone is generated. For in view of these facts it seems hard, as Dobson has pointed out, to regard it as the product of the sun's ultraviolet radiation.

No search seems yet to have been made for ozone in the planetary atmospheres. In the cases of Mars, Jupiter and Saturn at all events, the problem is not at first sight specially difficult. It would not be easy to establish a positive result, however, unless the atmospheres of these planets possess an ozone stratum at least comparable in effective thickness with the terrestrial one.

POSSIBILITY OF UNKNOWN ELEMENTS OF HIGH ATOMIC WEIGHT.

Although we are no longer at liberty to postulate unknown light elements, we are free up to the present to postulate heavier ones than any known terrestrially. Jeans, as is well known, has made use of this hypothesis to explain the origin of stellar energy. In common with other authorities he provides it by the destruction of matter, with radiation of the equivalent quantity of energy (MC^2) demanded by the theory of relativity. So far there seems to be fairly general agreement. The difficulties arise when we come to the question of stability, and here agreement is not general. Jeans considers that the source must liberate energy at a rate independent of the temperature. I am not qualified, and shall not attempt, to discuss this point. The object of postulating unknown heavy elements is to endow them with the property of going out of existence spontaneously at a rate which is independent of external condition, except in so far as ionisation, which involves the removal of some of the electrons from the neighbourhood of protons, tends to hinder the process.

In the known radioactive elements we have of course instances of unstable forms of matter, and Jeans regards these as transitional; but it must be admitted that substances which undergo spontaneous disintegration do not at first sight form an altogether satisfactory halfway house between those which are quite stable on the one side and those which

spontaneously go out of existence on the other. Then we have to explain why these heavy atoms are not found on the earth, which, it is generally agreed, originally formed part of the same mass as the sun. Jeans mentions this difficulty, and gives reasons for thinking that the heavy elements would sink to the interior of the mass, so that the earth, formed from the exterior part of it, would not contain them. That a *vera causa* is here appealed to cannot be doubted; but there seem to be some difficulties in assuming that it operates with enough precision to secure the desired result.

The list of known elements ends with uranium, and we must notice that the occupants of the 92 places up to and including uranium in the list, nearly all answer to their proper numbers when the roll is called. The only exceptions are 85 and 87. And he would be a rash philosopher who attached much importance to these vacant places, which may be filled up any day. Roughly speaking, we may say that the elements up to uranium are all present, and the higher members assumed to exist in the stars are all absent. It is putting a heavy burden on the mechanism of gravitational separation to expect it to achieve this result. The inventors of ore-dressing machinery would, I should imagine, despair of accomplishing anything like it.

Nature works on a vast scale and with plenty of time at her disposal, and it may well be urged that we must be careful of measuring her possible achievements by our own. We may ask, however, whether the more direct indications available suggest that she has in fact made this separation. If there is this cut between the atomic numbers 92 and 93, we should expect most of 92 to have gone into limbo in order to ensure *the whole* of 93 having done so. Yet 92 (uranium) is a relatively abundant element compared with most, being in fact No. 25 on the list of abundance in igneous rocks, according to the estimate of Clark and Washington. Again, we happen to be in a position to say that on the earth at least, uranium, so far from having sunk to the centre, is concentrated near the surface. This is inferred from the known outflow of heat from the earth, which is difficult to reconcile with the observed amount of radioactive matter near the surface, and impossible to reconcile with the existence of a comparable amount in the interior.

Assuming that uranium exists on the sun as on the earth, then, as first pointed out by Lindemann, there are strong grounds for thinking that it must be in course of formation there, for the life of uranium is too short in comparison with the probable age of the sun to allow us to suppose otherwise. Those who remember the early development of radioactivity will recall that a parallel argument was successfully used by Rutherford to prove that radium must have originated on the earth before the fact was directly proved that it is being generated here. Radium (it was later shown) is generated from a parent body of higher atomic weight, namely uranium. Jeans would regard the origin of uranium itself as analogous, and if this analogy is accepted it would require the presence of an element of still higher atomic weight, capable of undergoing radioactive disintegration, but, it is to be observed, incapable, *ex hypothesi*, of dissolving entirely into radiation.

No doubt these are very deep waters, and we can hardly expect at

present to fathom them. What would really be most helpful would be a theory of atomic structure in sufficiently definite agreement with experiment as regards known elements to enable us to proceed to investigate the properties of elements of higher number than 92 with confidence. On the general question of whether the evolution of elements has proceeded from the simple to the complex, or from the complex to the simple, it does not seem to me very much to the purpose to appeal to evolutionary doctrine and the analogy of organic evolution, in favour of the former alternative. Is it not more to the point that the only cases we can observe (radioactive changes and those induced by radioactive bombardment) are of the latter class? At present this is a question of scientific taste. Perhaps it is not irrelevant to remark that even in organic evolution degeneration of organisms sometimes occurs, and I do not know whether our biological colleagues are in a position to assert that the whole course of organic evolution may not at some future time be reversed by a change of conditions. At all events it is something to have formulated the more restricted question of whether uranium now comes into being on the sun by a synthetic or an analytic process. It would seem that this is a well-framed question, and that the answer can hardly be either *both* or *neither*.

CONCLUSION.

The great success of theoretical investigations in recent times naturally leads enterprising spirits to use them not only in interpreting what we know or can verify by observation, but to lead us into regions where experiment is not available as a check. I believe that this does nothing but good in times like ours, when there is no danger of the doctrines even of a master being unduly pressed, if the evidence of observed fact turns against them. At the same time, we must not expect too much of pure intellect unchecked by observation. Theories that do not stand the test of time pass for the most part into complete oblivion, and we are apt to forget how appallingly large a mass of wreckage the total of them represents. The next generation remembers chiefly those that survive, and does not take full advantage of the lesson of how easy it is for an apparently inevitable conclusion to be wrong. Unless the argument carries its own verification by some accurate and previously unforeseen numerical coincidence, it is hard indeed to tell if we are on the right track.

Though some of the problems we have been discussing have been only partially or not at all resolved, yet many possible points of approach are opening to our view.

The attack on Nature's secrets is now conducted along a long line of battle. No sooner does the defence show signs of crumbling at any point than an eager crowd of combatants, not restrained by any undue respect for the traditional modes of scientific thinking, are ready to throw themselves into the breach. The great array of trained workers in pure science existing in the modern community is powerfully reinforced by workers in applied science, who are backed by the resources of the industrial and financial world and hand back to the physical laboratory the devices which had their birth there in a form infinitely strengthened in power and convenience of application. Thus rearmed with weapons of greater power

and precision, pure science advances again to the attack of fresh territory, and so the process goes on at an ever accelerating rate.. How long this acceleration is destined to continue it is impossible to say. It shows few signs of abating at present. But for all that I for one am not afraid that our successors will be able to complain that we have left them no more worlds to conquer.

SECTION B.—CHEMISTRY.

THE RELATION OF ORGANIC CHEMISTRY TO BIOLOGY

ADDRESS BY

PROFESSOR GEORGE BARGER, M.A., D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

SINCE the British Association first met in South Africa, Afrikaans has become an official language, and I will therefore take as my point of departure the Dutch word for chemistry, still commonly used in Holland : Scheikunde, the science of separating. The German analogue, 'Scheidungskunst,' hardly applies to chemistry as a whole, and is now mainly restricted to the separation of gold and silver—'parting,' as we say. Since the purification of a substance is merely the separation of impurities, and since purification constitutes no small part of the labours of the chemist, whether he be an inorganic, an organic, or a biochemist, it will be seen that the Dutch term is really apt ; it is, moreover, an accurate description of chemical analysis ; perhaps it will appeal least to those physical chemists who are content to leave the purification of their materials to the manufacturer. Since, in the last resort, we are dependent on naturally occurring materials, which hardly ever occur in a state of purity, it follows that the early chemists were even more concerned with separating one substance from another than many of us are to-day. Progress was at first limited to mineral substances capable of withstanding powerful reagents and a high temperature ; much of the old chemistry is concerned with the heavy metals. The substances formed in such large numbers by living beings are much less stable, and their isolation demands a special technique. It is significant that, in spite of their knowledge of the smelting of ores, of the manufacture of glass, and of many other arts, the ancients failed to distil alcohol. Later, the chemical investigation of organic material was apt to consist in destructive distillation, naturally adding little to knowledge. Only the more volatile and stable substances could be isolated in this fashion. Thus, in 1770, four acids were known, formic and acetic, obtained by distillation, succinic and benzoic, obtained by sublimation. Oxalates and tartrates were known, but not the free acids. By distilling alcohol with strong acids, ether, ethyl nitrate, and ethyl chloride had been obtained.¹ The wet method of separation, by crystallisation from solution, had scarcely been applied to organic substances. Nevertheless Marggraf of Berlin had isolated beet sugar in 1747 ; this chemist was also the first to purify glucose.

¹ I have taken these and some other details from Graebe's *Geschichte der organischen Chemie*.

An important systematic advance was made by C. W. Scheele (1742–1786), whose contributions to organic chemistry are almost as important as his discovery of oxygen. Scheele was a pharmacist, and most of the early chemists were trained as such, or as physicians, from the iatro-chemical period onwards. This old connection between chemistry and medicine was, however, hardly a biological one. Joseph Black's work on fixed air and the mild alkalies indeed originated in medicine, from his M.D. dissertation, 'De humore acido a cibis orto et magnesia alba,' but the subsequent developments of Black's work were not biological in character. Again, although Berzelius was trained as a physician, his work had little connection with biology. The use of vegetable drugs, however, led pharmacists to examine the constituents of plants, and thus the foundations of descriptive biochemistry were laid. Scheele investigated a number of organic acids in the wet way. He obtained tartaric acid in 1769, and later benzoic acid by boiling gum benzoin with lime. He first prepared lactic acid (1780) from sour milk, and mucic acid by oxidation of milk sugar. When soon afterwards mucic acid was also obtained from gum tragacanth, it became evident that one and the same substance may be derived from both animal and vegetable sources. Oxalic acid was obtained from the acid potassium salt in *Oxalis acetosella*, and shown to be identical with an oxidation product of cane sugar. Scheele also obtained citric, malic, and even gallic acid by crystallisation from solution. Of more general biological interest is his discovery of uric acid, of glycerol and of hydrocyanic acid; the last (acidum berolinense) by heating potassium ferrocyanide with dilute sulphuric acid. Scheele's discovery that esterification is greatly furthered by the presence of mineral acids later became important in connection with catalysis, but theoretical speculations were foreign to his nature, and he was not greatly concerned with the essential character of acids. Such questions appealed more strongly to Lavoisier, who improved the nomenclature of organic acids and also investigated alcoholic fermentation, a biochemical process which early engaged the attention of chemists.

Of course both Scheele and Lavoisier benefited biology more by discovering and investigating oxygen than by their contributions to organic chemistry. These latter contributions already illustrate two trends in organic chemical research. There were those who, like Lavoisier, were attracted by theoretical questions. Such were Gay-Lussac, Bunsen, and Frankland, who investigated radicles; Dumas, Gerhardt, and Laurent, who evolved the theory of substitution and of types; Wurtz, Hofmann, and Williamson, the forerunners of Kekulé in establishing the theory of structure, which soon became the common ground of all organic chemists.

A knowledge of structure gave a great impetus to organic synthesis, not only in the laboratory, for theoretical purposes, but also in the factory for practical uses; the manufacture of dyes, of synthetic drugs, of explosives became an important industry. The number of known carbon compounds grew at an enormous rate. In 1883 some 20,000 were registered in Richter's Lexicon, in 1899 74,000, in 1910 144,000, and the number now is probably not much short of a quarter of a million. More than half of these are derived from coal tar, and only a small proportion occur

in animals and plants. Instead of being the chemistry of organised beings, organic chemistry became the chemistry of carbon compounds. Until the present century the proportion of chemists who, like Scheele, were interested in natural products steadily declined, and biology became of little interest to chemists as a whole, but physiologists have more and more realised the importance of chemistry for their subject and the intermediate subject of biochemistry has rapidly developed.

The systematic study of natural products, inaugurated by Scheele, was at first continued most successfully in France, by Fourcroy, Vauquelin, and their pupils. Both were at the Jardin des Plantes, and Vauquelin was afterwards at the Faculté de Médecine. Conjointly they discovered urea and hippuric acid, Vauquelin allantoin and asparagin. In 1800 about twenty acids were known, but only one hydrocarbon (ethylene) and one alcohol.

The knowledge of organic substances slowly increased. Braconnot, a pharmacist and later director of the botanic garden at Nancy, examined plants and discovered substances such as salicin and ellagic acid, of no particular importance to physiology, but also obtained glucose from cellulose (linen) and 'sucre de gélatine' or glycine from glue, thus making two fundamental observations in biochemistry. Kirchhoff, a German pharmacist, working at St. Petersburg, had already shown in 1811 that glucose is formed from starch, and investigated the process of malting. In 1833 Payen and Persoz discovered the first enzyme diastase and in 1827 a medical practitioner of London, W. Prout, better known to chemists in another connection, could say in a paper: 'On the ultimate composition of simple alimentary substances' that they might be arranged in three classes, 'the saccharine, the oily, and the albuminous.'

Thus, quite early, pharmacists and physicians brought organic chemistry into close relation with biology, but further advance could not take place without the development of organic analysis, by Gay-Lussac and Thénard (1810), by Berzelius, Liebig, and others. At first the difficulties were enormous. In 1814 Berzelius wrote to Berthollet: 'J'ai employé un travail de 12 mois à l'analyse de seulement 14 substances végétales.' But by analysis Gay-Lussac was able to establish the fundamental equation for the fermentation of glucose into alcohol and carbon dioxide, and the first systematic advance in biochemistry, also due to analysis, was Chevreul's great work on the fats. Chevreul doubtless acquired an interest in natural substances from his teacher Vauquelin; he was attracted to the study of fats by the accidental crystallisation of a potassium soap from hydrolysed lard. He altogether isolated seven fatty acids and discovered cholesterol and cetyl alcohol. In his 'Analyse organique,' published in 1824, he already considered as contrary to the spirit of science the assumption that animal and vegetable substances could not be produced artificially. In that very year, 1824, Wöhler obtained oxalic acid from cyanogen, the first synthesis of a vital product, if we except Scheele's production of cyanides from carbon, potassium carbonate, and ammonium chloride. Four years later, in 1828, Wöhler's synthesis of urea attracted universal attention, and since then much labour has been expended on the synthesis of vital products as an ultimate proof of their structure.

Wöhler had apparently no connection with medicine or pharmacy, but Liebig was a pharmaceutical apprentice for one year, Frankland a druggist's assistant, Dumas, Schorlemmer, and even Wilhelmy, who investigated the kinetics of sugar hydrolysis, were pharmacists. Gmelin, Mitscherlich, Wurtz, and Cannizzaro studied medicine; even in the present century medically qualified professors of general chemistry survived (Crum Brown, Emerson Reynolds). The pharmacists soon found a special field of research in alkaloids, essential oils, and other products of the *materia medica*. Within a few years of the recognition of the first organic base, morphine, by the German pharmacist Sertürner, a dozen alkaloids had been discovered, mostly in France, by Pelletier and Caventou, professors at the *Ecole de Pharmacie*. It is presumably due to this institution, and to the high standard of pharmaceutical education in France that the scientific output of French pharmacists has been so long maintained. For recent times we may refer to Bourquelot, professor at the *Ecole de Pharmacie*, and to Charles and Georges Tanret, father and son, both practical pharmacists, who not only made important contributions to our knowledge of drugs but also to that of sugars. In Germany contributions of pharmacists to organic chemistry were of less importance, compared with the great developments in university research, inaugurated by Liebig and fostered by the German states. In Britain the state did very little for the universities and nothing for pharmaceutical teaching; although British pharmacists have the exclusive legal right to call themselves 'chemists' the state has not helped them to justify the title. At first the British themselves contributed little to organic chemistry; of the pioneers Faraday, Frankland, Perkin, and Williamson, only two were teachers. The sojourn of Hofmann in London, from 1845-1865, from the age of twenty-seven to that of forty-seven, was of the greatest influence on the development of organic chemistry in England, but it did not lead to biological applications. Particularly through the inauguration of the dye industry, by Hofmann's pupil, Perkin, and Mansfield, attention was directed to practical problems. The determining factor in Hofmann's decision to return to Germany as professor at Berlin is stated to have been the more idealistic attitude towards science of German students, in contrast to the practical sense of his English pupils, who desired knowledge of a more utilitarian kind. Germany was not yet industrialised, and the insistence on research in her universities favoured 'Naturforschung' and the study of products of vegetable and animal origin. Characteristically, Liebig's practical applications of chemistry to agriculture seem to have attracted more attention in Britain than in his own country. But in physiological chemistry Germany began to lead the way, as witnessed by the foundation of Maly's *Jahresbericht über die Fortschritte der Tierchemie* (1871) and of Hoppe-Seyler's *Zeitschrift für physiologische Chemie* (1877). The latter remained for a generation the only journal exclusively devoted to the new border line subject and even now is perhaps more largely concerned with organic chemistry than its contemporaries.

German organic chemists investigated not only substances such as alkaloids, colouring matters, and terpenes, which are mostly restricted to a few species, but systematically studied whole classes of biologically

important compounds, in the same way as Chevreul had much earlier investigated the fats. Such was Baeyer's work on uric acid and its derivatives. Emil Fischer, after a short period of work on triphenylmethane, devoted the labours of a lifetime to the purines, the simpler carbohydrates, the proteins, and the tannins.

As a result of Fischer's work the new science of biochemistry was firmly established in the beginning of the present century, and the year 1906 marked its recognition in three countries, when three new journals first appeared: the *Biochemische Zeitschrift* in Germany, the *Biochemical Journal* in Britain, and the *Journal of Biological Chemistry* in America; the first named absorbed Hofmeister's *Beiträge zur chemischen Physiologie und Pathologie*, already a competitor of Hoppe-Seyler's *Zeitschrift*. The interest of German organic chemists in substances of general biological importance may be further illustrated by Willstätter's work on chlorophyll, carotin, the anthocyanins and enzymes, by Windaus' investigations on the sterols, by Wieland's work on the bile acids and by Hans Fischer's study of the porphyrins, which recently resulted in the synthesis of hæmin.

British organic chemists appear to be more interested in theoretical problems. I find that during the years 1927 and 1928 about 580 papers on organic chemistry were published by the Chemical Society, constituting much the largest portion of the Journal. Of these rather less than 20 per cent. may be said to deal with natural products and were inspired largely by W. H. Perkin (himself a pupil of Baeyer) and by Perkin's pupil, Robinson. About 45 per cent. of British papers on organic chemistry are more or less directly concerned with such theoretical questions as stereo-chemistry, the nature of valency, reactivity, tautomerism, and the remaining 35 per cent. deal with the synthesis of new compounds devoid of theoretical and biological interest, although occasionally having practical importance. German organic chemists seem to be more interested in natural products. I estimate that of the organic chemical papers in the *Berichte* for 1928 about 40 per cent. are concerned directly or indirectly with such substances. It should not be supposed that organic chemical theory is wholly unconnected with biology. Two examples out of many will show the contrary. When a protein is 'racesimed' as far as possible, by Kossel's method, by leaving it for some weeks at 37° in half-normal alkali, it is found that certain amino-acids retain their optical activity and these Dakin has assumed to be the ones with free carboxyl groups, situated at the ends of chains. The others undergo racemisation probably because in their case tautomerism is possible:



On subsequent acid hydrolysis the amino-acid $\text{NH}_2\text{CR}'\text{H}\cdot\text{COOH}$ would be racemic, but $\text{NH}_2\text{CR}''\text{H}\cdot\text{COOH}$ optically active. Dakin's views were first applied by Dudley and Woodman to show a structural difference between the caseinogens from cow's milk and sheep's milk, which had

been considered by some to be identical. Elementary analysis shows no difference :

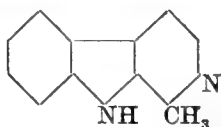
	C	H	N	S	P
Cow . . .	52.96	7.05	15.65	0.758	0.847
Sheep . . .	52.92	7.05	15.60	0.771	0.809

and individual amino-acids are obtained in the same amounts after hydrolysis. After racemisation, however, Dudley and Woodman found the tyrosine from cow's caseinogen to be wholly inactive, that from the sheep fully active. In the former animal the tyrosine is probably inside the molecule, in the latter it is on the periphery. We are thus able to discover differences in the intimate pattern of the molecule. Dakin and Dale connected these differences with antigenic specificity. Crystallised albumins from the whites of hens' and ducks' eggs are very similar and seem to be composed of the same units in equal amounts, but Dakin found that three amino-acids, leucine, aspartic acid, and histidine, behave differently to alkali in the two molecules, and appear to occupy different places. Hen's albumin has some aspartic acid but no leucine or histidine on the periphery; duck's albumin, on the other hand, has no aspartic acid, but some leucine and histidine on the outside of the molecule. By the very sensitive anaphylactic reaction of the isolated guinea pig's uterus, Dale showed that the two proteins are specifically different as antigens. Differences in arrangement, even of the same amino-acids, help to differentiate the proteins of various species. It is on the diversity of the proteins that the difference of species is based.

Another recent example of the application of organic chemical theory to biology is due to Stedman. Having traced the miotic action of physostigmine to a urethane grouping, he synthesised a number of urethanes of simple dimethylamino phenols, *e.g.* $\text{R.NH.CO.O.C}_6\text{H}_4\text{N(CH}_3)_2$. The physiological activities of the tertiary bases is generally in the order ortho and para > meta, but on conversion into quarternary salts the ortho and para become less active, the meta more so and the order is meta > ortho or para. This recalls the reactivities of disubstituted benzene derivatives, which have of late been studied in connection with the polarity theory.

Whilst organic chemists are often eager to investigate the constitution of animal and vegetable substances, they are less ready to undertake the preliminaries of purification and isolation, and are therefore less apt to discover new ones. By esterification and by the use of a high vacuum Emil Fischer made the monamino acids amenable to fractional distillation, a standard operation of organic chemistry. He discovered several new members of the group. But most substances of physiological interest require a special technique, on the development of which the biochemist may spend much labour. Thus Kossel showed how to separate the purine and pyrimidine bases of the cell nucleus, and the important diamino-acids, histidine, arginine, and lysine. Hopkins, by his special reagent, was able to isolate tryptophane, the parent substance of indigo, long after indigo itself was being manufactured synthetically. Dakin found that monoamino acids can be extracted from aqueous solution by butyl alcohol, and using this new technique and Foreman's method

of separating aspartic and glutamic acids by their calcium salts, Dakin discovered hydroxyglutamic acid, an entirely unsuspected unit of protein. A knowledge of the structure of amino-acids may throw light on how other nitrogenous constituents arise, particularly in plants. As an example, the most recently discovered amino-acid may be quoted. The American bacteriologist Mueller found in casein and other proteins a new constituent containing sulphur, quite different from the well-known cystine. Dr. Coyne and I have recently established its constitution by synthesis. It turns out to be γ -methylthiol- α -amino-n-butyric acid, $\text{CH}_3\cdot\text{S}\cdot\text{CH}_2\cdot\text{CH}(\text{NH}_2)\text{COOH}$, and we named it methionine. The methylthiol grouping at once indicates that it is the source of methylmercaptan, the occurrence of which in putrefaction was known, although not hitherto intelligible. Methionine is evidently also the parent substance of cheirolin occurring in the seeds of the wallflower and of other Cruciferae. Schneider had long ago established for this substance the remarkable constitution $\text{CH}_3\cdot\text{SO}_2\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{N}\cdot\text{CS}$. We now see at once that cheirolin is the thiocarbimide of oxidised and decarboxylated methionine. Similarly Perkin and Robinson connected the chemistry of harmine and harmaline with tryptophane when they showed that the mysterious base $\text{C}_{12}\text{H}_{10}\text{N}_2$, which Hopkins and Cole obtained by oxidising tryptophane $\text{C}_{11}\text{H}_{12}\text{O}_2\text{N}_2$ with ferric chloride, is identical with harman



This observation not only settled the constitution of the alkaloids in question, but also explained the fitful yield of the oxidation product of tryptophane, which, after decarboxylation, had condensed with acetaldehyde. Soon afterwards Späth showed that harman itself occurs in nature, as the alkaloid aribine, which had been given the erroneous formula $\text{C}_{23}\text{H}_{20}\text{N}_4$. It is becoming increasingly evident that many alkaloids arise by condensation of amino-acid residues. Mezcaline and other alkaloids of Cactaceae are closely connected with phenylalanine and tyrosine, as Späth has shown, and the mode of origin of isoquinoline alkaloids from aromatic amino-acids has also become clear. Harmine, harmaline, physostigmine, and rutaecarpine are all derived from tryptophane, and it looks as if the same is true of other alkaloids whose constitution, like that of strychnine and of brucine, remains obscure.

The isolation of some natural substances, of great physiological interest, is beset with difficulties because they are present in minute amount and have not the convenient solubility relations which facilitate the separation of the alkaloids. This applies to the hormones present in animal tissues. Here the American slaughter-houses provide valuable facilities, and it is significant that adrenaline, thyroxine, and insulin were first crystallised in America, although the constitution of the two former hormones was later established in Europe, where also their synthesis was effected, that of thyroxine only a few years ago, through the brilliant work of Harington. The difficulties of isolating vitamins is still more formidable; in the case of the antineuritic vitamin B, which is almost

certainly a fairly simple substance, susceptible to attack by the methods of organic chemistry, most progress towards isolation has been achieved by selective adsorption and elution, the methods employed by Willstätter for enzymes. The discovery by Rosenheim and Windaus that vitamin D is formed by the irradiation of ergosterol has suddenly brought into prominence a substance which before was but a curiosity, chiefly known through the work of the French pharmacist, Tanret. At the same time the interest of biochemists in photochemistry has been stimulated, as well as in the extensive work of Windaus on the structure of cholesterol, which the latter had already shown to be connected with the bile acids, largely investigated by Wieland.

The sudden emergence of ergosterol into prominence does not stand alone; another of Tanret's ergot substances, ergothioneine, at first also an isolated curiosity, has acquired more general significance because it has been found in mammalian red corpuscles; it is likely that this will ultimately lead to the discovery in proteins of yet another sulphur-containing amino-acid, possibly a thiol histidine. Altogether ergot has yielded more substances of general biological interest than any other single plant.

The above examples of the relation between biological and organic chemical work relate to that division of biochemistry which may be termed descriptive. A knowledge of structure is also necessary in dynamic biochemistry, the study of the transformations which substances undergo in the living organism. The recognition of the fats as esters, and their behaviour to fat-splitting enzymes, the transformation of starch into sugar under the influence of diastase, the end-products of alcoholic fermentation, all these were early discoveries in dynamic biochemistry. But just as the organic chemist may wish to know the mechanism of a reaction, for instance of the Skraup synthesis of quinoline, so the biochemist wishes to know the intermediate steps in the transformation of say glucose into alcohol. The detection of these stages of metabolism is a matter of considerable difficulty, since under normal conditions the intermediate substances generally disappear as rapidly as they are formed. They have to be trapped by suitable means, as did Neuberg with acetaldehyde in alcoholic fermentation, or the metabolic process may sometimes be cut short, by using an isolated organ, such as the surviving liver, or the precursor of the intermediate substance may be administered in large excess. Very little has been learned in this respect from the higher plants. The very process of photosynthesis is still beset with obscurity in spite of a plausible hypothesis; we know next to nothing about transformation of carbohydrate into fats, and *vice versa*, and in particular we are ignorant of the stages by which amino-acids are formed in plants from nitrates and carbohydrates; we simply do not know how the proteins of living beings originate. Nor have the higher plants given us much information of the way in which their fats, carbohydrates, and proteins are ultimately broken down. Our knowledge of catabolism is principally derived from the animal world. It is found that the breakdown does not always occur in the manner in which the organic chemist would expect. Thus an organic chemist presented with the problem of transforming stearic acid into palmitic might brominate in the alpha position, and

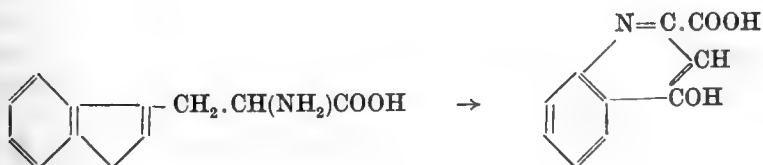
break down the corresponding α -hydroxy acid ; or he might do a Hofmann degradation on the amide. In either case he would get an acid with 17 carbon atoms, and have to repeat the degradation in order to obtain palmitic acid. Knoop has shown, however, that in the animal organism the β -carbon atom is attacked so that the chain is shortened by two carbon atoms at a time, an acid with 18 carbon atoms being converted successively into one with 16, 14, 12, etc. In accordance with this scheme the principal fatty acids in nature are those with an even number of carbon atoms. Knoop established this by feeding ω -phenyl fatty acids ; those with an even number of methylene groups in the side chain were converted into benzoic acid and appeared in the urine as hippuric, those with an odd number of methylene groups yielded phenyl acetic acid and were excreted as phenaceturic acid.

Instead of using a resistant phenyl group and the whole animal, fatty acids themselves and the isolated liver may be used to establish the same result. Embden perfused the ten lowest members of the series of fatty acids through a surviving liver and obtained acetone formation only with those having an even number of carbon atoms ; they are converted by β -oxidation finally to acetoacetic acid, from which acetone results. Dakin found in hydrogen peroxide an oxidising agent which closely imitates the biochemical method *in vitro* and at a low temperature ; thus butyric acid gives acetoacetic, and the higher fatty acids give methyl ketones, with loss of carbon dioxide.

The same method of oxidation seems to occur in the vegetable kingdom, for plants are apt to contain ketones with an even number of carbon atoms in addition to a methyl group. Thus methylamyl-, methylheptyl- and methylnonyl-ketones of essential oils doubtless result from the decarboxylation of β -keto acids, as in Dakin's experiment, with hydrogen peroxide.

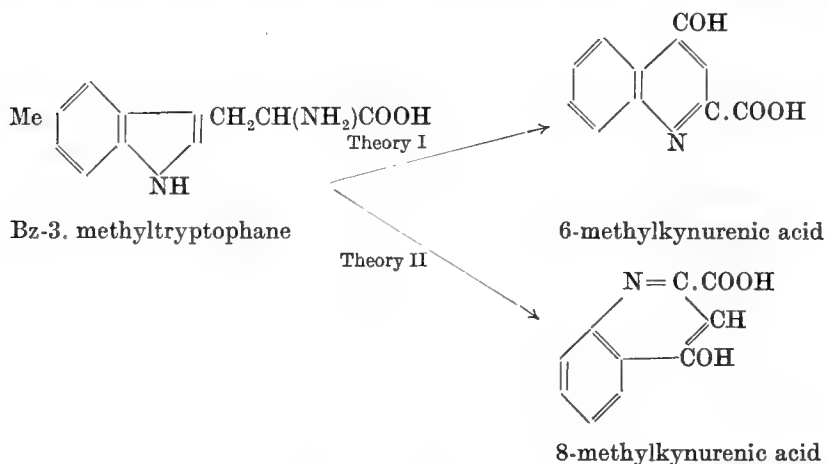
The degradation of amino-acids in the body also proceeds contrary to the expectations of the organic chemist. If he were asked to bring about the degradation by gentle stages he would doubtless first convert the α -amino into the α -hydroxy acid. The organism forms the α -keto acid, however, as shown by Neubauer and by Knoop. This biochemical result suggested to Knoop an interesting and unlooked for synthesis of amino-acids *in vitro*, by reversing the normal breakdown. He shook solutions of α -keto acids, containing also ammonia and platinum black, in a hydrogen atmosphere when the corresponding amino-acid resulted by the reduction of the hypothetical imino compound.

The transformation of tryptophane into kynurenic acid may be quoted as a particular problem of metabolism to which a good deal of organic chemistry has been applied. When large amounts of tryptophane, or of meat containing this amino acid, are given to dogs they excrete in their urine kynurenic-acid, a quinoline derivative



and the question is which of the two nitrogen atoms of tryptophane survives. Is the pyrrole ring enlarged to a pyridine ring, as when indole is treated with chloroform and alkali, or is the pyrrole ring oxidised and does the pyridine ring arise from the side chain of tryptophane? It is almost certain that the latter alternative holds good.

In 1914 Ellinger and Matsuoka synthesised Pr-2. methyltryptophane, but could not obtain any methylkynurenic acid from it; and having overlooked their publication, Ewins and I a few years afterwards made the same amino-acid, and obtained the same negative result. Later in Edinburgh I suggested to Dr. W. Robson the synthesis of a tryptophane with a methyl group in the benzene nucleus, which would not interfere with the oxidation of the pyrrole ring. He synthesised Bz-3. methyltryptophane and also 6-methyl and 8-methylkynurenic acids, which might be expected to be formed from it according to the two rival theories :



Even this very considerable expenditure of organic chemical effort did not absolutely settle the matter, for the Bz methyltryptophane did not yield any kynurenic acid either. Robson found, however, that 6-methylkynurenic acid passes through the body unchanged, whereas 8-methylkynurenic acid is completely burnt. It is therefore likely that it is formed from Bz-3. methyltryptophane as a transitory intermediate product, for if 6-methylkynurenic acid were formed, the latter would resist oxidation. Robson concluded therefore, that the single nitrogen atom of kynurenic acid is the one from the side chain of tryptophane (Theory II). Ellinger and Matsuoka, in 1920, after obtaining kynurenic acid from indole pyruvic acid, concluded that the pyrrole ring is indeed opened up, but that its nitrogen atom ultimately survives in kynurenic acid (Theory I). The weakness in the latter's reasoning is that indole pyruvic acid might conceivably be converted in the body into tryptophane, and may not yield kynurenic acid directly.

The example of kynurenic acid will serve to show that there is scope for the application of organic chemistry to the problems of intermediate metabolism, and also the difficulties involved in drawing definite conclusions.

The first stage in the degradation of fatty acids and of amino-acids

seems pretty well established, and analogies *in vitro* have been found. Other problems are more obscure. Why is the benzene nucleus in phenylalanine oxidised, but not that in benzoic acid? And what is the mechanism in the former case? Why is p-hydroxyphenyl pyruvic acid easily oxidised, and the corresponding lactic acid not? Why is d-phenylglycine easily oxidised and l-phenylglycine excreted almost unchanged? Altogether the processes by which organic substances are burnt to carbon dioxide and water, by atmospheric molecular oxygen, at a low temperature, are still very puzzling, although Dakin, Hopkins, Knoop, Warburg, Wieland, and others have done much towards their elucidation. In the study of the chemical processes, as in that of the chemical constituents of living organisms, there is much scope for the application of organic chemistry, and in addition, physical chemistry requires to be utilised.

I have endeavoured, by the mention of the above examples, to indicate the importance of organic chemistry both to descriptive and dynamic biochemistry, and thus to physiology. This is its main field of application to biological science, but there are others. There is no reason why an animal or a plant should be recognised entirely by its morphological characters, but systematists, not being chemists, are naturally apt to rely on what they can see, rather than what they can test for. It is very rarely that chemical characteristics are mentioned, although most floras refer to the odour of trimethylamine in the Stinking Goosefoot (*Chenopodium vulvaria*) and that of sulphide oil in *Sisymbrium Alliaria*. With micro-organisms it is different. The bacteriologist cannot always distinguish one bacillus from another merely by looking at it, nor even by staining it. He has to grow it in a variety of sugar solutions, and see whether it attacks these. In order to differentiate typhoid from paratyphoid, he grows them in dulcitol solution, with neutral red, which may or may not be changed owing to the production of an organic acid from the sugar. In order to encourage an organism to grow, which is normally swamped by other species, he may use specific disinfectants, such as brilliant green and other dyes. The relation between microbiology and organic chemistry is beneficial to both. The list of organic substances which can be produced by micro-organisms on an industrial scale, mostly from carbohydrates, is a growing one. During the world war the water power of Switzerland could temporarily compete with the fermentation industry in producing alcohol (*via* calcium carbide), but later the potato reasserted its superiority. The same war period saw the industrial production of glycerol by yeast, and the production of acetone and butyl alcohol by bacteria, both from carbohydrates. The peculiar metabolism of many micro-organisms still awaits utilisation.

The group of plants in which chemical constituents have been most widely used in classification is that of the Lichens. Lichenologists have long used chemical reactions with potassium hydroxide, bleaching powder and ferric chloride, for the identification of species and genera, and some 200 characteristic benzene derivatives have been isolated. In Phanerogams the taxonomic value of the chemical constituents is slight. Substances of obvious metabolic significance may extend throughout a whole order; thus inulin occurs as reserve carbohydrate in all divisions of the Compositae.

Probably the most extensive attempt to use chemical constituents for botanical classification has been made by R. T. Baker and H. G. Smith, in the case of the Australian genus *Eucalyptus* with about 200 species: the essential oils from well over half of these have been examined. Baker and Smith trace a relation between the venation of the mature leaves and the composition of their essential oil. The genus is thus divided into fairly well-marked groups, and it is possible to suggest the probable constituents of the oil of a given species by examining the venation of the leaves, and, conversely, by chemical investigation of the oil to gain a clue to the species. Maiden, the botanical expert on *Eucalyptus*, has not always agreed with the classification of the chemists, but upon occasion has discovered morphological differences after a delimitation of species had been proposed on chemical grounds.

Among characteristic plant constituents perhaps most chemical labour has been expended in the alkaloids, which are usually restricted to a particular order, genus, or species. An increased knowledge of the various amino-acids of protein, and a study of many alkaloids has in many cases indicated a plausible way in which the alkaloids, particularly those containing an isoquinoline nucleus, may arise from aromatic amino-acids, by decarboxylation and ring formation from the side chain, but we are still very much in the dark as to the physiological importance of alkaloids to the plant. Nor is it easy to trace a connection between chemical structure and botanical classification. Thus, within the same genus differently constituted alkaloids may occur, or certain species may contain an alkaloid and others not. Some thirty-five species of *Cytisus* were examined by Plugge and Rauwerda; about half contain cytisine, half do not. Yet cytisine occurs in *Ulex*, *Genista*, and several other genera of Leguminosae. It may even happen that in one and the same species the alkaloids change according to the age of the plant. Thus *Papaver orientale* contains during the vegetative period only thebaine, which is almost entirely replaced by isothebaine after the death of the aerial parts of the plant. Obviously it is very difficult under these circumstances to draw conclusions as to a taxonomic relationship. The only wide generalisation which seems to me justified is that the large group of isoquinoline alkaloids are characteristic of the rather primitive cohort, Ranales, and the related order, Papaveraceae.

The main biological interest of alkaloids is not botanical, in their distribution, but pharmacological, in their action. This leads to a mention of the great developments in synthetic drugs, due to organic chemistry. In particular there is great scope for the organic chemist in chemotherapy, the combating of general infections of the host by synthetic drugs. The production of salvarsan which had made such a great change to the treatment of syphilis and other protozoal diseases and the subsequent introduction of germanin (or Bayer 205) in the treatment of sleeping sickness indicate great possibilities of applying organic chemistry to this particular department of medicine, and constitute a link between workers in very different fields.

I have called attention to the many points of contact between organic chemistry and biology in the past and present and if finally I am permitted to draw a conclusion it would be an educational one. I hold it to be

desirable that biologists should have at least an elementary knowledge of organic chemistry, in spite of the difficulties imposed by ever-increasing specialisation in science. These difficulties are particularly felt in apportioning the time available for medical education among the many subjects of a crowded curriculum, and may to some extent be met by a careful consideration of what is really useful. The chemical training of the physician (and of the biologist) should not be identical with the preliminary training of the professional chemist, although it still is so in many universities. In order to save time much elementary chemistry, particularly inorganic, must be abandoned, thus making room for those aspects of the subject which have biological applications. This differentiation between the chemical needs of various groups of students requires special courses, and teachers who have a sympathetic understanding of the peculiar needs of their students, medical and biological. After writing this sentence, I found a similar one in last year's address to Section I at Glasgow, by Professor Lovatt Evans. 'The solution to the difficulty [of the medical curriculum] lies, in my opinion, in the exercise of a sympathetic understanding on the part of specialist teachers of the difficulties of the student and a proper perspective of the relation of his own subject to the requirements of the curriculum as a whole.' I need hardly say I agree entirely with this. I also welcome another sentence from the same address: 'It is significant that at the present time a steadily increasing number of young highly trained organic chemists consider it worth their while to turn to biochemistry; their welcome entry into our ranks gives us fresh hope and faith in our future, as well as in theirs.'

Professor Lovatt Evans also discusses the question, 'much debated in private, though little in public,' whether a biochemist should be primarily a chemist or a biologist. He sees no reason why the biochemist should not be both. I imagine the biochemist cannot be both equally from the outset, but he may aspire to be both, or alternatively, biochemists can be made both out of chemists and out of biologists. Once more I heartily agree with Professor Lovatt Evans when he writes: 'If he must have one label, it is better that of the chemist, provided always that the biochemist works in the closest possible association with the physiologist. This is most essential if both are not to be deprived of much valuable interchange of ideas and, on a lower plane, of materials and apparatus. In fact, I am convinced that within the limits of administrative possibility, the greater the variety of workers brought together the better the results.'

SECTION C.—GEOLOGY.

THE UTILITY OF GEOLOGICAL SURVEYS TO COLONIES AND PROTECTORATES OF THE BRITISH EMPIRE.

ADDRESS BY

SIR ALBERT E. KITSON, C.M.G., C.B.E.

PRESIDENT OF THE SECTION.

THE importance and value of a geological survey to a country have long been recognised by all progressive nations that desire to utilise the mineral resources with which Nature has endowed them. But though such value is fully appreciated and freely acknowledged by all thoughtful, observant people, the nation as a whole has no understanding of it, and no definite views on the matter.

The rapid advance of science, and the application of the wonders of science to industry, in practically all divisions of the activities of mankind, are incontrovertible facts, and no nation or community under present-day conditions can afford to neglect to utilise all the assistance that science can give towards increase in production and reduction in cost of the fruits of the industries upon which that nation is mainly or largely dependent for its existence and advancement.

Where the question of cost is not an insuperable barrier to its establishment, a geological survey is formed. As regards our Empire, not only the United Kingdom, but the British Dominions—India, Canada, Newfoundland, Australia, New Zealand, and South Africa—long since established such surveys and recognised their value. All these surveys have done most valuable work in the determination of the nature, not only of the pure geology of their countries, but also of the economic geology, in the form of mineral deposits, of the precious metals, base metals, non-metallic minerals and rocks, gem-stones, coal, gas, oil, and underground water-supplies. The direction and personnel of the Geological Surveys, the maps and reports published, the information and assistance given to general industry, prospecting and mining, are recognised to be of the highest order, and to have benefited these countries immeasurably more than is yet realised by them.

In his Presidential Address before this Section of the British Association at Newcastle-on-Tyne in 1916, Professor W. S. Boulton said—‘We have ceased to hear rumours of Treasury misgivings as to whether the Geological Survey can justify, on financial grounds, its continued existence. When we call to mind the untold wealth of information and fact in the published maps, sections and memoirs, the enormous value of such knowledge to mining, civil engineering, agriculture, and education, and indirectly to the development of the mineral resources of the whole Empire, and then

reflect that the total annual cost of the Geological Survey of England, Wales, Scotland, and Ireland is somewhere near £20,000—less, that is to say, than the salary and fees we have been accustomed to pay every year to a single Law Officer of the Crown—we should find it difficult to bear patiently with any narrow or short-sighted official view.'

Granted, then, the value of a Geological Survey to a country already well established, and with many lucrative sources of production and wealth, how much more so is it to a young country, dependent to a greater or less extent for its existence during its infancy or adolescence, upon the financial benefactions of its guardian or sponsor; a country the revenue of which in some cases is less than its expenditure; and the significance of whose natural features is scarcely understood, with its mineral resources almost unknown and entirely undeveloped. Surely a young country needs to have its possible economic mineral importance investigated and determined by competent persons specially trained in this respect. Thus, as regards all that appertains to geology in all its branches and connections, the trained geologist is the person to whom appeal should be made for such purpose.

For the following information I am indebted to Dr. C. A. Matley:—
'The earliest record there is apparently of a geological survey of a Colony is that of Trinidad, as shown in the Introductory Notice and Appendix O of the Report on the Geology of Trinidad, published as one of the "Memoirs of the Geological Survey of Great Britain," in 1860. This says: "The Geological Survey of Trinidad originated with the late Sir William Molesworth, who, in 1855, when Secretary of State for the Colonies, induced the Lords Commissioners of the Treasury to appoint competent Geologists to undertake a general Survey of the Economic Geology of Trinidad, and the other West India Colonies." The cost of the survey and publication of results were borne by the Home and Local Governments. Three Memoirs were published, the first in 1860, on Trinidad, the second in 1869, on Jamaica and the adjacent islands of Anguilla and Sombrero; and the third in 1875, on British Guiana.

'This official geological survey of Jamaica, done between 1859 and 1866, was a creditable production of pioneer work. On the scientific side notable advances were made in the knowledge of the formations, fossils and tectonics of the island. On the economic side valuable information was gained of the metalliferous and non-metalliferous resources of Jamaica, and the important rôle played by the various geological formations in controlling the surface and underground water-supply.'

Further valuable work on the geology of the island of Jamaica was done by Dr. Matley, from October, 1921, to near the middle of 1924, and important economic results obtained by him, specially with regard to water-supply, road-stones, and fossiliferous zones of the rocks.

The Colonies do not seem to have had any more surveys of this kind till, through the broad vision and enlightened policy of the Colonial Office, Mineral Surveys were established in Southern Nigeria in 1903, Northern Nigeria in 1904, Ceylon in 1903, Nyasaland in 1906. These surveys did useful work and made important discoveries of mineral deposits. They were succeeded by Geological Surveys, with broader interests, as mentioned hereunder.

The Colonies and Protectorates that now have Geological Surveys in

full operation and doing valuable work are Nigeria, the Gold Coast, and Sierra Leone in West Africa; in Central and East Africa—Uganda and Nyasaland, with the Anglo-Egyptian Sudan, and the Mandated Territory of Tanganyika; and the Federated Malay States. Among those which have had surveys for certain periods, but which have been varied, suspended, or concluded, are Jamaica, British Honduras, British Guiana, Gambia, Somaliland, Zanzibar, Ceylon, and the Falkland Islands. Geological advice is being given in Ceylon, Palestine, and Somaliland. In those now without surveys much useful work was done, and the discontinuance of operations was due to various causes.

The interests of the geologist should be wide, and thus be available in various manners for the benefit of the country. His opportunities are perhaps greater than those of any other of the professions practised in a young country. His travels through many different districts enable him to see and note much that relates directly not only to his own department, but also in some respects to other departments, members of which may be unable at the time to make independent examinations, or to those of departments not then established. Observations thus made can be communicated to such departments, or published in the Annual Reports of his own, for the information of all people interested therein.

The following remarks of Professor W. W. Watts in his Presidential Address—'Geology in the Service of Man'—to this Section of the British Association at Toronto, in 1924, are appropriate: 'It is because of the variety and intensity of observation essential to geological surveying . . . that the geologist must necessarily become a physiographer and geographer. There is a limit to the perfection of topographic maps and surveys, even when, as in the United States, there is close co-operation between the Topographic and Geological Surveys; and it is the duty of the geologist to take note of innumerable features which have no delineation, still less explanation on such maps. The geologist is probably the only class of person who has to traverse large areas with his eyes open, not to one class of phenomena only, but to all that can help him to decide questions of concealed structure. . . . Nor can he confine himself to the purely physiographic aspect of his area. He is led into bypaths . . . and many facts with regard to the distribution of animals and plants, and of the dwellings, occupations and characteristics of the people, can scarcely escape his observation; neither can he shut his eyes to historic and prehistoric facts. Thus a geologist is generally possessed of a store of knowledge reaching far beyond the strict bounds of his science.'

There is a great deal of misconception regarding the functions of a Geological Survey, using the term geological in its broadest sense. By many it is thought to deal with the rocks of a country, to describe them, and to show on maps and in reports their divisions, disposition, and distribution; perhaps also to include the economic minerals, such as coal, brown coal, lignite, rock-salt, ores of iron, manganese, copper, nickel, zinc and lead; or valuable gem-stones, such as diamonds, rubies, sapphires and opals.

But there is very little, if any, recognition of the great part that geology plays in a most unobtrusive manner in connection with mining, agriculture, stock-raising, water-supply, forestry, public works, sanitation, geography, and education. The ramifications of geology are great. Its interconnec-

tion is close in some respects with other sciences, more especially with chemistry, zoology, botany, engineering and physics.

This is not the place to discuss fully these various aspects, but let us consider them briefly in their economic relations.

Chemistry tells us of what constituents any material—organic or inorganic—is composed. It shows us also how and under what natural conditions changes in the chemical compositions of rocks and minerals have taken place, what these changes signify, and their importance or otherwise to mankind—the differences between economic minerals which at the surface have certain characters, but which at varying depths below the surface have entirely different ones.

Palæozoology shows us which remains of the former fauna of a region are still preserved in its rock-record, and Palæobotany similarly with respect to the flora. These sciences come to the assistance of Geology and reveal the true significance of these vestiges of creation that have been preserved. They determine their nature and indicate to which section of the genealogical tree of life they belong. Thus Palæozoology, with its record of the fauna from the Cambrian to the Recent period, shows us the divisions, systems, and series of rocks containing certain types of fossils, specially those which are characteristic, such as graptolites and trilobites of the Palæozoic division, the great reptiles of the Mesozoic, the mammals of the Kainozoic.

Palæobotany shows that certain types of plants characteristic of the Carboniferous system are distinctly associated with strata containing seams of black coal; others, of the Jurassic, with beds of a younger black coal; still others, upward in geological time, of the Cretaceous system or the Kainozoic division, with brown coal and lignite, with their remains of characteristic plants, or of plants and mollusca.

Therefore, when strata are found by him with fossils similar to those mentioned the geologist knows to what system of rocks they belong, and can then, in the case of the plants, hope to find beds of the kind of coal usually found occurring with them; or, conversely, when a bed of coal is found he may search the associated beds for fossils to determine the system. Thus, it can be seen that a geological training is required to note the significance of any such discovery.

The importance of the remote possessions of a great Empire is dependent upon many factors—such as natural resources and their situation, physical character of the country, lines of communication and transport, nature of climate, soils and water-supply, density and distribution of population, character of the peoples, conditions regarding agriculture and pasturage. To develop these fully there should be a Government with wide vision and foresight, capable and energetic, with a broad outlook on possibilities of development, and ready to assist financially and sympathetically all proposals that show reasonable prospects of economic success.

A little consideration will show that a Geological Survey may have an important influence upon the material advancement of such a possession—a very important one in some cases, and less so in others.

The extent to which geology is of benefit depends upon the geological formations of the country. Some countries have conditions much more favourable than others for the possession of natural resources that are of

economic value. These may consist of deposits of fuels and ores of the metals indispensable for the industrial uses of man under twentieth century conditions of life ; or they may be of such minerals as are used by mankind for personal adornment and gratification. They may consist of materials that are essential for the construction and maintenance of railways, roads, bridges, and buildings ; or they may comprise the occurrence of valuable supplies of water for domestic and stock purposes. They may embrace all these categories, and be really valuable in every material sense.

On the other hand, the colony may be a small one, known to have its limitations as regards the possession of geological features unlikely, on investigation, to prove the presence of mineral deposits of economic importance, or to possess inorganic materials and supplies of direct or indirect value to a country. Such a country does not require a Geological Survey. It is, however, worthy of a careful geological investigation and report, which could be made in a comparatively short time, and which might possibly prove that the pessimistic surmise of its resources was wrong. There are, however, many colonies with vast areas of unknown resources, and it is to them specially that the substance of this address applies.

The Colonies and Protectorates of the British Empire are almost without exception in the tropics. Many of them are wholly or partly in zones which are blessed with an abundant rainfall, and covered with dense forests or low vegetation. Some comprise areas of low rainfall, and, in consequence, have seasonally arid conditions, and little vegetation.

A geological survey of the former is necessarily slow, for the dense vegetation and depth of soil effectually obscure the nature of the underlying rocks and what they contain. In such country much time, labour, and expense are necessary to examine carefully the watercourses, by cutting and clearing lines along them and through the dense bush between them. Nevertheless, it should be remembered that such country may have valuable mineral deposits lying hidden within a few yards of any line of traverse through the forest, and merely awaiting discovery. In areas of low rainfall and scanty vegetation, however, the examination of the country is rendered much easier and can be done much more quickly and thoroughly.

The numerous interests that need to be considered in connection with the development of any country, more or less uncivilised, involve the establishment of various public departments. Those dealing directly with the natural wealth of the country are principally Geological Survey, Mining, Agriculture, Veterinary, Water-Supply and Public Works, and to a less degree Lands Survey, Forestry, and Public Health. Obviously the most important department, so far as relates to the investigation of rocks, minerals, fuels, and water-supply, is that of Geological Survey, and on its activities a few remarks may be made.

The interpretation of the geology of a country involves a knowledge of the kinds of rocks occurring in it, their division mainly into Sedimentary, Metamorphic, and Igneous ; the relation of these to one another, both structurally and chronologically ; the separation of these main groups into their various divisions, and the nature of the rocks in these divisions, with a view to assistance towards a knowledge of what may be of economic value among them.

In a young, undeveloped country, with a small revenue and a large expenditure, such as is often the case, it behoves one to attach greater importance to the economic than to the purely scientific side of geology.

In his Presidential Address—‘Functions of a State Geological Survey’—to the Mining and Geological Institute of India, in 1907, Sir Thos. Holland says:—‘The official geologist in this country is bound by the terms of his appointment to remember that, either directly or indirectly, his work should aim in the long run at the development of our mineral resources’; also that—‘in general, the field-work of the Geological Survey ends with what is known as the exploratory stage, as regards minerals of economic value: that is, the stage at which sufficient information is obtained to warrant the outlay of money for systematic prospecting operations. The official operations normally end with the publication of the information available at this stage; but the Geological Survey still takes an interest in the work of prospecting and exploitation.’ This address deals particularly with the development of Indian metalliferous minerals and gives valuable information about the production of ores of aluminium (bauxite), iron, manganese, and copper, and the disposal of them in competition with similar ores from other countries.

But before the economic can be properly appraised it is necessary to know what relation the scientific has to it. It is, therefore, imperative to keep this always in view. Let us consider the great division of sedimentary rocks and compare them with the rocks known in old countries, where their characteristics and associations have been thoroughly ascertained.

Geological science has shown that for the sake of convenience sedimentary rocks have been placed in various groups, ranging from very ancient ones to those at present in a state of formation. Were these always present in their natural order of succession the matter would be an easy one, but since, in no part of the world, is there anything approaching a complete sequence or record—for there have been numberless changes in the relation between sea and land—the relative positions in sequence of these sediments have to be ascertained by some means. The most reliable are the types of fossils they contain.

Further, the occurrence of subterranean water, as artesian, is dependent on the character of the strata and their disposition—that is the association of pervious and impervious beds, which are gently folded so as to form basins in which the surface water can collect under hydrostatic pressure, and be prevented from flowing away until tapped by a bore.

This information is obtainable only by persons familiar with geology, and before any attempt be made to bore for artesian water a geological examination is necessary. Blind boring on sites selected by people without that knowledge has meant the expenditure of much money, labour and time, often without useful results. The same can be said of boring for oil and coal. Large sums have been thrown away through boring operations at unsuitable places and the continuance of boring into underlying rocks devoid of oil and coal. Professor J. W. Gregory records¹ the statement of J. E. Pogue, in ‘Economics of Petroleum’ (1921, p. 243),

¹ Gregory, J. W. ‘The Elements of Economic Geology,’ p. 1 (Methuen).

that of an extensive series of American oil-well records 85 per cent. of the wells sunk in accordance with geological advice proved successful, whereas of those sunk at random only 5 per cent. were productive. In his Presidential Address to this Section at the Bournemouth meeting in 1919, Dr. J. W. Evans, C.B.E., says :—‘ The sum total of the funds which have been uselessly expended in this country alone in hopeless explorations for minerals, in complete disregard of the most obvious geological evidence, would have been sufficient to defray many times over the cost of a complete scientific underground survey.’

One of many examples of useless boring for water, coal and oil, that have come under my own notice may be given. In this case boring for oil with a percussion drill was continued for several thousand feet in igneous and metamorphic rocks, underlying petroliferous sediments. My examination of the core of the bore showed that material thought to be sandy micaceous clay of the petroliferous series, of marine Kainozoic age, was really comminuted biotite-schist, of a much older division of rocks, barren of oil. Had the core material been submitted to a geologist from time to time during the progress of boring its nature would have been recognised at once, and the expenditure of several thousand pounds sterling, as well as a great deal of time and labour, would have been saved. In this case the Kainozoic rocks were fossiliferous, but their lowermost portion consisted of material derived from rocks similar to those of the underlying metamorphics, a fact that might be advanced as sufficient to excuse the mistake made by the technical men in charge of boring operations. But, since a great thickness of fossiliferous rocks had been bored through and then material found not only showing no fossils, but possessing sufficient evidence to distinguish it from the sediments that had been bored previously, this mistake should not have been made.

The Directors of the Geological Surveys of several Colonies have informed me that many thousands of pounds have been spent fruitlessly in boring at unsuitable places in the attempt to get good supplies of underground water.

These failures were not due to incompetent technical management of boring operations, but to a lack of geological knowledge of rock structure, of the nature of the sediments and rocks bored, the significance of fossils, and the correct interpretation of the evidence from the material obtained. Under existing conditions regarding the qualifications of boring engineers there are limitations to the value of their technical knowledge, unassisted by geological training or timely advice.

Some bedded rocks, as shale, mudstone and clay, when inclined and saturated, or nearly so, with water, and under great superincumbent pressure, are unstable, and often give much trouble in various engineering works, such as dams, and railway and canal cuttings, as for instance the Culebra cut, Panama Canal. There are many examples of railway- and road-cuttings in which there has been so much sliding of beds that the ground on the inslope side has had to be cut back in numerous benches, some for upwards of 100 yards. Geological advice, if obtained before operations had far advanced, would certainly, in some instances, have shown a means of averting trouble by preventing the saturation of unstable beds.

Timely geological advice would have been useful in a recent case, in connection with the excavation and exposure in a moist atmosphere of carbonaceous shales, containing much marcasite—the more easily decayable form of iron sulphide—occurring as large nodules or discoidal masses. This material swells considerably on decay and induces spontaneous combustion. Its use in the reclamation of a low-lying area caused settlement of the surface till the marcasite was converted into hydrous oxide of iron.

FUNCTIONS OF A GEOLOGICAL SURVEY OF A COLONY.

In considering this kind of geological survey it should be remembered that it differs greatly from the geological surveys of old countries in the mode of operations necessary.

The fact that it functions in a young, undeveloped and comparatively unknown country, probably devoid of detailed maps, and with poor and slow means of transport, compels it to adopt methods and undertake duties entirely foreign to surveys long established. These surveys are able to place at once, on accurate maps, while in the field, the geological features of any district that is being examined. The geologist of the Colony, however, has not the great benefit of such maps, nor usually any reliable maps with good contours, and so, where field mapping in detail has to be done, or special areas surveyed, a ground-work map has to be made by himself. The collection of all information and the preparation of the topographical map involve the expenditure of by far the greater portion of the time, labour, and expense of such a survey. This may represent upwards of four-fifths of the time in certain types of country, the geology of which is not of great variety. When comparing, therefore, the character and production of maps and reports of a young colony with those of Great Britain, due allowance should be made for these different conditions.

Opinions differ as to how the work is to be commenced. One geologist may consider it advisable to make first a series of rapid reconnaissances through the various districts, along natural boundaries such as the coast-line, large rivers, main paths or roads, railways, if any, or through promising belts of country; then later a series of rapid cross-traverses connecting with the first series, and later still numbers of others linking the two series in various directions. This method enables him to get, in the quickest manner, a general knowledge of the geology of the country as a whole. The mapping, in detail, of the geology, in conformance with a mathematical scheme of division of the country, can be done later as opportunity offers.

Another geologist may prefer to survey in detail certain areas, such as a known mining field, a belt of country, or the main lines of communication, leaving outlying districts for later work.

Both methods have their advantages and disadvantages, but these cannot be discussed in this address. The particular features of the country and the wishes of the Government will determine the system of work.

The following remarks indicate various activities of a survey of this kind.

Reconnaissances and rapid surveys through the country, noting specially the physiography, nature of rocks with their structural features (anticlines, synclines, strike, dip, foliation, cleavage, jointing, faults, dykes, and reefs), nature, occurrence and testing of minerals in rocks and gravels of streams by crushing and panning. Kinds of soils, nature and volumes of streams regarding irrigation and water-power, underground water supplies, sites for dams and reservoirs, archæological notes, collection of rocks, minerals and concentrates, with general reports on all, and preliminary special reports on mineral deposits and other interesting features.

Detailed surveys and reports on particular areas, deposits and occurrences, such as mentioned in the preceding paragraph.

Special reports on the country along routes of proposed railways, water-power, sanitation, and other matters.

Assistance and advice to other Departments on geological matters.

Surface and underground surveys of mines, with reports, maps, and sections.

Advice to mining companies and prospectors on the examination of their mines, areas, and specimens of rocks and minerals.

Assays, analyses and other determinations of samples of minerals collected by the survey, or received from the public, with reports on them.

Advice to Government regarding operations of prospectors and prevention of fraudulent flotation of companies.

Assistance to educational institutions by information supplied and descriptive museum collections.

Scientific (mainly geological and geographical) reports, with microscopical and chemical descriptions of rocks, maps and photographs.

Special examination of minerals in concentrates and reports on them.

Publication of reports, maps, sections, assays, analyses, &c.

Formation of a geological museum, mainly of practical geology, with descriptions and uses of the materials therein.

There are numbers of other kinds of geological work that need enlargements of the staffs of the Geological Surveys before they can be undertaken, such as observations with regard to :—

Transport of sediment and chemical character of water in streams.

Inland denudation, and coastal erosion.

Underground flow of water through rocks.

Decay of rocks under tropical conditions.

Museum.—The formation of a Museum of practical geology, such as that of the British Geological Survey at Jermyn Street, London, but on a much smaller scale, and to have in addition local specimens, is a most valuable adjunct to a Survey. It is also of great assistance to all workers specially in Geology, Geography, Agriculture and Engineering, and of interest to all who have any love for natural history, or wish to understand something of the ground they travel over and the materials that cover it. A museum of this kind should have small collections of representative rocks of the great divisions grouped under (1) mode of origin, such as various kinds of igneous, sedimentary, metamorphic, chemical, æolian; (2) broad general divisions of each of the groups specified in (1); (3) a stratigraphical table showing the various chronological divisions into which sedimentary rocks have been grouped, together with indications

showing the relative chronological position of the numerous igneous rocks which are intrusive into them, or interbedded with them, as lava flows and tuffs (volcanic ashes); (4) typical fossils, characteristic of the main divisions of geological time, particularly those which are associated with economic minerals, such as coal, brown coal, lignite, oil-shale and mineral oil; (5) typical fuels; (6) the common metallic and non-metallic minerals (as far as possible these specimens should not be only of the beautiful, showy type that are seen in great museums, but also of the weather-beaten ones, such as one finds at or near the surface, during the course of prospecting for minerals); (7) gemstones; (8) clays, sands, gravels, pigments, abrasives, refractories; (9) building, ornamental and engineering stones (with a section illustrating the various kinds of limestone and their products); (10) a collection showing the natural weathering of rocks; (11) concentrates, and their minerals; (12) a collection, specially for use in agriculture and forestry, and in assistance in the proper determination and mode of occurrence of rocks, the nature of which is more or less obscure. This should comprise groups of five or six specimens representing:—

(a) Fresh (undecayed), or non-disintegrating rock; (b) partially decayed, or disintegrating one, showing a crust of decayed rock round a core of fresh rock; (c) completely decayed rock; (d) subsoil from (c); (e) soil immediately above the subsoil; (f) soil mixed with humus.

A separate small collection of the typical rocks and minerals of the colony should also be shown.

Since many rocks decay into soils which in colour differ greatly from the fresh or decaying rocks, it can be seen that a study of examples of this kind enables one to form shrewd conclusions regarding the rocks from which the soils have been derived, especially in tropical countries where decay has been so great—to upwards of 50 feet—that no rock, fresh or decaying, can be seen in natural sections, such as low cliffs, channels and landslips; or artificial ones, as railway- and road-cuttings, drains, shafts, and pits. Thus the soil can be determined as a sedentary one—derived directly from the rock underlying—or one of transport, consisting of material usually quite different from a soil derivable from the rocks underlying. One useful aid to determination of a sedentary soil is the presence of lines of quartz representing disintegrated veins of that mineral. To appreciate fully the importance of specimens of this kind it is advisable to compare a series of groups of them.

Accompanying these specimens there should be a diagram of transverse sections showing in profile the nature of the weathering from the surface soil to the underlying rock at the base, the chemical and physical analyses of the soil, the nature of the drainage, &c.

Photographs and diagrams, showing various aspects and phases of all occurrences, with descriptive and explanatory notes, should be put with the specimens.

GOLD COAST METHOD OF RAPID SURVEY IN UNMAPPED COUNTRY.

It may be advisable to describe very briefly the main features of the method adopted in the Gold Coast in the rapid examination of country possessing no reliable maps.

Traverses are made, by bicycle mainly, with (*a*) the prismatic or pocket compass, for direction; (*b*) cyclometer, or measuring wheel, for distance; (*c*) aneroid barometer, with thermometer attached, for altitude and temperature; and (*d*) watch, for time.

On leaving a camp all four observations are taken, but instead of the traverse being tabulated in columns as usual—which method gives no graphic idea of the orientation of the traverse—the graphic method is used. This shows at once the direction being taken, for the bearing of each line is roughly plotted in the field-book, as to direction and length, and a continuous traverse obtained, in which, in its relative position, each natural feature is placed. The observations embrace features such as sites of camps, and prominent landmarks, edges of stream flats and banks, water-levels, gullies, tops of rises or ridges or plateaux, edges of plateaux or hills, huts, villages, outcrops of rocks, showing dips, strikes, characters and any special features. All four observations (*a—d*) are taken at each of such places, except the occasional omission of that for time when stoppages are frequent. But at places where the stoppage is for ten minutes or more the time observation also is taken on leaving, for the purpose of correction for altitude because of change in air-pressure.

As far as possible samples of the gravels of all streams, as well as the loam beside outcrops of quartz reefs and dykes, and the material from road-gutters or paths, are panned, and concentrates of heavy minerals obtained. (In certain types of country panning is the most useful aid to prospecting, not only in the discovery of gems and stable metallic minerals, such as native gold, platinoid minerals, oxides of tin, thorium, titanium, iron, chromium, tungsten, and manganese, but also of many rock-forming minerals, which indicate the probable character of the rocks at the spot, or in the basin of the stream tested.) Specimens of rocks and samples of quartz are collected for reference, museum purposes, microscopic examination of thin sections, or testing by assay, analysis, or other methods. Coal, lignite, limestone, and other economic rocks, brick and pottery clays, and pigments are sought; also fossils, which, if found, are used to determine the age of the strata associated with them.

In addition to the general observations indicated, notes are made of the colour, kind, and thickness of soil, the nature of the vegetation, size and kind of stream and gravel, and measurement of volume of water—when there is opportunity, and if of possible economic value, with regard to domestic supplies and possible hydro-electric power and irrigation.

It will thus be seen that the geologist in a new country, by taking the opportunity to make the observations mentioned in the last section is helping his colleagues in other departments by collecting evidence of probable future value.

On the completion of several traverses roughly parallel with one another, particularly if they have been made across the strike of the rocks, a large amount of useful geological and topographical information is available. From this a map can be prepared, with possibly a connection with some definitely fixed point, and on it all natural features observed can be shown, sufficiently near to accuracy to serve fully the purpose of a map to a comparatively small scale.

To this can be added the geology and mineral occurrences, the various

geological divisions present in the area being shown in their respective colours, in agreement with the general scheme adopted for African geological surveys.

It will, therefore, be seen that in a young country which has no topographical survey of its own, or one which is only partly surveyed, it is imperative that some such method as outlined should be adopted before anything approaching a real representation of the features can be shown.

The only alternative to this is to attempt to describe with a flood of words what can be shown graphically as a picture, impressible on the visual memory by a brief examination of it.

It should be clearly understood that such is advocated only in the absence of an accurate groundwork of survey, such as that of the Ordnance Survey of Great Britain, a map upon which the geologist can at once place his geological information with accuracy, and thank Heaven and his country that he has such a map available.

Colonies such as these comprise some which are furnished with all Departments, others in which some of the smaller Departments have not yet been established. It is to a less advanced and less flourishing one that the following remarks specially refer. Such may not have a department of Lands Survey or of Water Supply, but it may have a Geological Survey. What then happens in the event of a discovery of some important deposit of mineral, or the collection of data of value respecting supplies of underground water, and of streams for the development of hydro-electric power? There is no Lands Survey Department, and no Water Supply Department, so there is no one whose special duty it is to make a topographical survey of the ground and produce a map therefrom, upon which a concession to Government can be obtained, if desired. Therefore the geologist makes the survey and the map. Similarly, the information respecting water supplies for domestic and stock purposes is collected by him, the streams crossed during his various traverses are examined, the volumes measured, possible sites for dams noted, and other useful data obtained for possible utilisation later of water-power for hydro-electric purposes. This information may not have any immediate value, or when obtained may not be regarded as of special interest, but conditions change and events happen rapidly in a young progressive country, so that often available information of this kind is found to be most opportune and useful.

There are several instances of the special assistance given by Geological Surveys, two of which in the Gold Coast may be mentioned. In 1917, on the discovery by that Survey of a large deposit of bauxite of high grade, the Government decided to obtain a concession over the deposit and surrounding country. The Geological Survey that year consisted solely of the Director, and as no Lands Survey Department then existed in the Colony he himself surveyed the boundaries and prepared a map therefrom, so that the concession could be obtained. He also surveyed in detail the area comprised by the deposits and prepared a map of it. Similarly, in the case of the large deposits of manganese ore found by the Survey.

It may be specially mentioned here that not only on the economic mineral side of geology is a geological survey of value to a colony. It is of much assistance to such departments as Agriculture, Forestry, Water

Supply and Public Works, as indicated previously, but a few remarks may be made to show how this is so.

Agriculture and Forestry.—The growth of plants, whether grasses, herbs or trees, is dependent on the chemical and physical properties of the soil, on the configuration of the land, and on climatic and other conditions. Since plant foods consist largely of certain rock-forming minerals in a soluble condition it is necessary to know what is the chemical character of the soil. This can be ascertained by analyses of samples collected by geologists, for much of the value of the analyses depends upon a careful determination of the types of rock forming the base of the subsoil. Where such consists wholly of one kind, as granite or dolerite, and the soil is one derived directly and wholly from it, a few analyses only are necessary to give results which may be generally applicable to the whole area. But this is not so with medium-bedded sedimentary rocks, comprising shales, mudstones, sandstones, grits and conglomerates, and the chemically-formed rocks, such as limestones, when these are of no great thickness. The nature of the soil derived from them varies very much and depends not only on the kinds of rocks—pervious or impervious—but also on their disposition—flat-bedded or inclined—and whether the ground is flat or undulating. For the ascertainment of the character and disposition of all these rocks the geologist is essential.

There is, however, another aspect to be considered. Many soils are not sedentary ones—derived directly from the underlying rocks—but are soils of transport. The character of the soil, or even the subsoil, often bears no genetic relation to the underlying rocks, and where such soil is of no great thickness a geological knowledge of the rocks underlying is necessary. In connection with irrigation the character of the soil of the supply channels needs the attention of the geologist. He should note if there is any crust of minerals on the soil, on the evaporation of water. If so, these minerals should be analysed to see if they are those injurious to plants, when in large proportion, such as certain sodium and magnesium salts. This is important in areas with soil derived directly from rocks of marine origin, particularly young clays, mudstones and sands deposited in brackish lagoons and estuaries. If these minerals be present he may be able to devise means by which the proportion of these harmful salts when in solution can be steadily reduced by flowing away with the water, and not being alternately and continuously precipitated and dissolved.

Water-Supply.—This question of water supply is one that concerns some colonies much more than others, but all are affected to some degree. In cases involving the conservation of the water of annual streams, the problem is dependent largely upon geological considerations. But where underground water is sought, whether of the character of an artesian supply, or due to seasonal rains, the problem is a much wider one, and may be difficult to settle satisfactorily. For artesian water, not only the configuration of the country, but also the disposition and nature of the rocks must be known before any conclusion can be formed as to the chances of success in obtaining such supplies. This is essentially a work for the geologist, and even for him it is quite likely that the evidence available in the district may be insufficient—owing to the absence of natural sections

—and that he may be compelled to wait for the result of boring done at spots indicated by him. Therefore, it is advisable that a geological report should precede the efforts to obtain permanent water supplies, and not, as so frequently happens, be asked for after one or more costly attempts have failed.

There are many examples in the Colonies of great waste of money in this manner, one case in which £20,000 was entirely wasted. A boring engineer usually has no knowledge of geology, or of the connection between stratigraphy and water supply, so he cannot be expected to do more than the mechanical part of the work.

Public Works.—To this department, perhaps, more so than to any other, the geological survey can be of assistance, specially with regard to—

- (1) The discovery of rocks, suitable for constructional purposes (such as for houses, bridges, drains, macadam), and of limestone, for lime, mortar, concrete, cement and house-washes.
- (2) The character of the foundations for bridges, large buildings, dams and breakwaters.
- (3) The nature of the rocks in areas where new roads are to be made.

This is mainly for possible variations of route with reduction of expense in construction and maintenance.

In country without outcrops of wide-spread suitable rocks, the help of the geologist is necessary to ascertain if any suitable ones occur as dykes or as beds among other folded unsuitable ones. If they do, then he can possibly trace their extensions into other localities.

In tropical climates, such as almost all our Colonies possess, the question of suitable road-metal becomes a pressing one. For this purpose it is advisable to get, if possible, rocks, such as dolerite, and gabbro, that are tough and hard, do not fracture naturally, but on abrasion yield a binding material, such as lime and iron, which under the action of intermittent saturation and evaporation becomes a cement.

The case of Jamaica may be cited where Dr. Matley, in the course of his geological investigations found many dykes of basic rocks eminently suitable for macadam and available for replacement of the limestone—a much inferior rock—then being used in the Colony. The attrition of limestone is so rapid that it is usually found to be unsuitable for roads with heavy traffic, but for light traffic it is excellent.

The search for limestone is an important duty of the geologist and should be continued until supplies of good limestone have been obtained, or failing that, till it seems quite unlikely that any such rocks exist in the country. A good limestone, if properly treated during the burning stage should produce good lime, and unless in remote districts under conditions of costly transport and burning it should be cheaper to produce it locally than to import it at great cost.

Quartzite, quartz-schist, and hornstone are used largely in some countries, but the excessive wear of tyres, the brittleness of the rocks, the serious effect of hard sharp-edged particles of dust on the lungs, the non-binding character of the material—all are against the use of this type of stone, despite the lower cost of excavation and breakage.

Hydro-Electric Power.—This question may be regarded as quite outside the duties of a geologist. A little consideration, however, will show that

the geologist has a good deal to do with it, especially where the question of dam-building and reservoir-formation is concerned.

For the construction of a dam, and the formation of a reservoir for hydro-electric purposes, it is of great importance to know the geology of the area and the nature of the rocks, whether soluble (as limestones) or insoluble; porous and brittle, or impervious and firm, and all the variations between; their normal or faulted condition; their disposition, strike and dip, the latter against or with the direction of the current.

The geologist has to help the engineer not only with regard to the suitability of the rocks at the site of the dam, but also in the whole of the area to be occupied by the proposed reservoir. As before mentioned, where a young colony has no special department and wishes to gather information respecting such water-power, it has to get help from another department. What more natural than that this should come from the geologist?

Sanitation.—Under the usual conditions for the disposal of nightsoil by burial in depots in the neighbourhood, where there is no proper sewerage or sterilisation system, the geological survey is able to help very considerably in the question of sanitation.

The glaring lack of consideration of this question, shown not infrequently, is a menace to the health of the people. There is an example known to me where all the nightsoil from a large town was buried on the ridge at the head of a valley in permeable soil, a valley in which were several wells from which the people were obtaining supplies of drinking water. The risk being run by using this water is illustrated by the case brought under notice some years ago on the Continent. In this the cause of an outbreak of typhoid fever could not be determined until a geologist said it was probably due to a nightsoil depot on the side of a ridge, several hundred yards distant from a spring on the opposite side of that ridge. He was laughed to scorn. But, by pouring water, stained with a permanent dye, on the depot he proved that the spring was taking the drainage from it. The geologist showed by scientific observation of the strata, that the beds were dipping through the ridge from the depot towards the spring.

All work of this kind should have the inspection of a geologist before anything is done; similarly, the sinking of wells in and near a town should be subject to his approval.

Military Training.—It may seem strange to say that geology can be useful to military science, but modern warfare has shown that to be the case. Prof. W. W. Watts, in his Presidential Address before this section at Toronto in 1924, has brought this clearly before us. He says, 'It will be readily admitted that geology has been of conspicuous service in connection with military operations in such ways as the siting of camps, trenches and dug-outs; while the minute study of the water-table in Northern France during the late war was not only of value in obtaining water supplies, but was of conspicuous utility in mining and counter-mining.'

Something can be said for geology in Africa in this connection. Military training and manœuvres are aided by a knowledge of the nature of the soil and underlying rocks, and of water supply. Country embracing all types from open to forest-capped plains, rises, hills and valleys, preferably in uninhabited or sparsely populated areas, are required for these opera-

tions. For purposes of domestic water supplies, where the district is lacking in surface water, and for indicating the nature of the soil, subsoil and underlying rocks for the excavation of trenches, earthworks and other purposes, the assistance of the geologist is most desirable, and this fact is now thoroughly recognised by military authorities. The supply of water that has to be transported long distances means great loss of time and opportunity, whereas geological advice can often enable it to be obtained on the spot by the sinking of shallow wells.

Geological Reports.—For the preparation of departmental reports on the physical features and geology of a young country—one that is for the special use of officials who may not be familiar with scientific or technical terms—it is desirable that language as simple as possible should be used in describing the various features. There are many scientific terms that are necessary to express what is desired, but it is advisable, when using them, to have accompanying explanations in parentheses, or a separate glossary, to which reference can be made. Whenever possible, however, it is preferable to avoid such terms, which are suitable only for a purely scientific report.

Aerial Survey.—A few words may be said on the use of the aeroplane—and hydroplane where suitable—for a knowledge of the broad topographical features such as the courses of streams, the nature of the drainage, hills, ranges, plains, and lakes of a country, and the assistance given to geological determination by that means. It is well known that certain rock masses weather with characteristic features. The geologist with ground experience of such will soon obtain aerial experience of the same, especially if during his flights he takes photographs from various angles and altitudes. This is particularly useful for open country where no thick forest hides the terrestrial features from view. A reconnaissance of this kind yields much valuable physiographic information of the country in a small fraction of the time required to traverse the same area by terrestrial means. It shows the routes by which the geological features can best be ascertained by the usual modes of transport on land. These planes also aid greatly in the transport of men and material.

Geophysical Prospecting.—Modern science has shown that a great deal of assistance can now be obtained by mechanical means, based on certain physical laws. The methods are the gravimetric, magnetic, seismic, acoustic or sonic, and electrical. They have now been tested and improved so much that the presence and approximate positions of bodies of certain substances below the surface of the ground—and of which there is no visible evidence—can be determined by their application.

These methods involve costly apparatus, high training, much time, expense and suitable conditions, both terrestrial and climatic, before they can be fully utilised, but of their importance and use there is no question of doubt. How far they can be applied to a young country depends upon natural conditions and the financial assistance available.

EXAMPLES OF BENEFITS TO COLONIES FROM SURVEY DISCOVERIES.

In order that a clear impression may be gained of the practical results following the activities of these surveys in Colonies a few remarks may be made regarding the development of certain mineral deposits dis-

covered solely and directly by the Geological and Mineral Surveys of three colonies. As there are definite results with figures available, these examples are given. There are also important discoveries by other such surveys in other colonies, but they either do not lend themselves definitely to being viewed in 'balance-sheet form,' or their deposits have not yet been developed.

Nigeria.—The mineral survey of Southern Nigeria discovered the large, black coal field in 1909, surveyed it in detail over the greater portion of a length of some 24 miles and width of 10 miles, and prepared a geological-topographical map of the country, showing altitudes, outcrops of coal and other information. Further work was done later and the coal-bearing area extended considerably. Mining operations by Government were commenced on the largest seam in 1916, and since then development has continued steadily. The total quantity of coal, in round numbers, produced from 1916 to March 31, 1928, is 2,210,000 tons, valued at the mine at £1,282,000.

The annual average over the three years ended March 31, 1928, is: coal production, 313,720 tons; revenue, £148,340; expenditure, £82,234; profit, £66,106. The total net profit to Government to March 31, 1928, is £452,559. The mine now employs some 30 Europeans and 2,400 natives. The coal is used principally by the Nigerian and Gold Coast Railways, the Nigerian tin mines and by shipping companies.

The total cost of the geological survey of Nigeria since its inception in 1919 to March 31, 1928, is approximately £68,700, and of the mineral survey of Southern Nigeria for the period 1903–1913, about £20,000, or a total of approximately £88,700. Thus the total profit to the Government from this one discovery by a Government geologist is more than five times the total cost of the geological and mineral surveys, while the average annual profit for the past three years is nearly nine times the average annual cost of the geological survey during the same period.

The surveys also discovered large and valuable deposits of good brown coal and lignite, some of which will probably be exploited later for the distillation of oil, or for sale of the coal in the form of briquettes. Besides these discoveries others were made of limestone of good quality in several districts, oil-shales, phosphate of lime—of value as a local fertiliser—excellent pottery, tile and brick clays, some lead-zinc-silver deposits, ornamental-, engineering- and building-stones. Doubtless some or all of these will be developed later and will prove of great value to the colony.

Gold Coast.—The specially important discoveries made by the geological survey of the Gold Coast are huge deposits of manganese ore and bauxite (aluminium ore), and widespread alluvial deposits of diamonds.

The manganese deposits were found in 1914 before the Great War, but not exploited until 1916, when the vital need for high-grade manganese ore caused the development of these deposits. Production of ore commenced in 1916, and the total production to March 31, 1928, is 1,785,643 tons of high-grade ore, valued at £3,350,706, free on board ship at Sekondi. Of this quantity the annual average during the past three years is 364,975 tons, valued at £656,132.

The Government Railway Department transports this ore to the seaboard at Sekondi, and has received, in round numbers, £550,000 for

freight to March 31, 1928. Besides this, the Railway Department has obtained large sums for freight on the great quantities of mining machinery, building materials and supplies transported from Sekondi to the mine.

In addition to the profit the Railway Department has made on freight of ore and supplies between the port and the mine, the Government gets a royalty of five per cent. on the profits of the company that owns the deposit. The mining royalty for the year 1927-28 was £10,000.

During the last three years the average number of Europeans engaged on the mine staff was 52, and of natives, 2,000.

Diamonds were first discovered in February, 1919. These diamonds, though small, are of very good quality, and have a ready sale for industrial purposes and jewellery.

Since mining operations were commenced in 1921 there has been a large progressive increase each year till, for the year ended March 31, 1929, the figures are: production, 648,343 carats; value £538,860; export duty paid, nearly £27,000. The total weight of diamonds produced is 1,824,630 carats, valued at £1,758,348, on which the Government has received roundly £87,900 from the export duty of five per cent. on the total value. The annual average for the past three years is: production, 520,572 carats; value, £482,157; export duty, £24,108; mine staff—Europeans, 21; natives, 1,163; cost of the Geological Survey, £9,342. The export duty received by Government for last year was nearly $2\frac{3}{4}$ times the cost of the Geological Survey for that year.

The benefit, therefore, that has accrued to the Gold Coast, directly and indirectly, from these two discoveries by the Geological Survey is apparent, and it will continue for a long period.

The Gold Coast has a great potential asset in its huge deposits of high grade bauxite—the total conservatively estimated quantity being upwards of 250 million tons. These deposits are not yet developed, owing mainly to the high cost of transport of bauxite to a port of shipment. Bauxite is an ore of low value and so cannot bear heavy charges for freight, but, with extension of railway communication and reduction of freight charges, the Colony should see a great development of this particular source of wealth, and a further mineral example be added to revenue from Geological Survey discoveries.

The Survey is also responsible for finding many occurrences of alluvial gold and some of reef gold, large deposits of iron ore (hæmatite), and good limestone, pottery, tile and brick clays, ornamental and general constructional stones, refractory substances, and smaller occurrences of tin, arsenic, molybdenum, copper, and platinum. None of these is as yet developed.

Sierra Leone.—The Geological Survey of this Colony is much younger than those of Nigeria and the Gold Coast. The Director has discovered large deposits of iron ore (hæmatite) of good quality, and considerable deposits of alluvial platinum and gold—all now being developed—besides occurrences of chromite, corundum, ilmenite, rutile, manganese, and graphite, all of them also minerals of economic value. If found on further examination to occur in promising quantities these deposits should prove to be of commercial value.

The West African Geological Surveys have no offices and laboratories

in the Colonies. During the dry and tornado seasons of the year the geologists are engaged on geological surveys and examinations of various kinds in the Colonies, but during the rainy season field work is suspended and the staffs return to England. In these respects their organisation differs from that of the other Colonies. The specimens of rocks and concentrates collected are then examined and distributed for various modes of treatment, and reports not made or completed on the Coast, as well as microscopic examination of thin sections of rocks, are done in London. The greater portion of the chemical work, such as assays and analyses, devolves upon the Imperial College of Science and Technology and the Imperial Institute under special arrangements.

The field work comprises mainly the geological mapping of areas, detailed surface and underground surveys of mining fields, detailed and rapid surveys of special areas and deposits, and such other matters as are indicated in another section of this address.

Sudan.—Owing to the geological character of the country the discoveries made by the Sudan Geological Survey are of non-metallic substances. They comprise valuable limestone deposits and underground water-supplies, while great assistance has been given in connection with sites for wells, tanks, dams, and buildings, and advice on building materials, fireclays, manufacture of salt, and other matters.

Tanganyika.—The energies of the Tanganyika Geological Survey, a young one, have been devoted very largely towards mapping certain areas, examining deposits of minerals found in the country, and reporting on geological aspects relative to railway location. Besides, much valuable advice and assistance have been given in various directions in connection with water-supplies.

Nyasaland.—The Geological and Mineral Surveys discovered large deposits of bauxite, and of limestone; also seams of coal and lignite, and deposits of asbestos, graphite, talc, tinstone, silver-lead, iron, and several other minerals. Owing to these discoveries a prospecting company has been formed with a view to examining the country thoroughly for minerals. Valuable work has been done in connection with the discovery of water-supplies in various districts, and most useful reports published.

Federated Malay States.—The energies of the Federated Malay States Survey have been devoted chiefly to the exploration of large areas with alluvial and lode tin, the determination of the character and age of certain intrusive rocks and limestone deposits, reports on mineral deposits, advice on road metal, sites for dams and roads, schemes for boring and prospecting, assays of ores and minerals.

As some of the benefits derived by Malaya from geological maps and advice given by the Survey may be mentioned the extension of tin-bearing country, in which dredging operations are now in progress, and the prevention of certain useless schemes proposed for boring for minerals, and prospecting for oil and water, thus saving much expense to the Government and private interests. As an example of non-acceptance of such advice may be cited a case in which nearly £20,000 was lost by a syndicate through boring for oil in a raised beach of dead shells, said by a tin miner to be an excellent indication of oil.

Uganda.—The operations of this Survey comprise mainly the geological mapping of the country. During such work areas likely to prove mineral-bearing are noted and mining companies and individual prospectors advised to test them. The Survey, has, however, made discoveries directly, or through prospectors acting on advice given. In one such instance it was proved that owing to earth-movements the drainage of a stream had been reversed, and the source of the gold in it was found to be down, instead of up, the course of the stream. Another interesting discovery, a recent one, which may prove to be valuable, was the occurrence, in considerable quantity, of a bismuth-tantalum mineral, new to science, in pegmatite.

A unique adjunct is a branch of seismological research, with a view to possible prediction of earthquakes, since Uganda is situated on an unstable portion of the earth's crust.

Ceylon.—The Mineral Survey of Ceylon made numbers of discoveries of valuable minerals, including deposits of limestone, mica, iron ore, monazite, corundum, gemstones, and various rarer minerals with radio-active properties, notably one new to science—thorianite (thorium oxide), which occurs both in gravels of streams and in dykes of pegmatite. Occurrences of platinum, and of manganese, chromium, molybdenum and copper minerals were noted, and hot saline springs found.

Jamaica.—Valuable stratigraphical work was done by this Survey through its discovery of fossils. By their aid the various zones of the strata were revealed, and the nature and occurrence of underground supplies of water determined. Numerous dykes and sills of basic rocks, from which can be obtained vast quantities of road-metal, much more durable than the limestone then being used, were discovered by the Survey.

British Honduras.—The operations of the Mineral Survey embraced the geological mapping of the country, and the preparation and publication of a useful geological sketch map. Large deposits of limestone were discovered, and occurrences of tinstone and molybdenite noted.

British Guiana.—Following the original survey already mentioned, much important work was done and reports published by the late Sir John Harrison, describing valuable occurrences of bauxite, diamonds, gold and palladium. Other useful reports issued later were by Messrs. H. J. C. Connolly and Smith Bracewell, on the geology and economic features of the gold and diamond fields.

Gambia.—A rapid geological survey of this small colony has been made by Dr. W. G. G. Cooper of the Gold Coast Geological Survey, and a comprehensive report with map, sections and photographs published. Many interesting features were noted, and useful information given, specially with regard to water-supply and brick and pottery clays.

Somaliland.—A brief examination by Mr. R. A. Farquharson of a portion of this Protectorate resulted in his discovery of seams of black coal and lignite, and of occurrences of lead and strontium minerals. Other minerals and rocks were noted—among them salt, barite, oil-shale, marble and large deposits of gypsum. Many useful remarks were also made regarding water-supplies and soil, and a report with sketch map published.

Zanzibar.—An important report with map, sections and photographs

on the geological survey of these islands, by Mr. G. M. Stockley, has been published. Among the economic materials found are clays and limestones for building and road purposes, and gypsum—possibly of value for manure for the clove plantations. Useful information regarding water-supply was obtained and many fossils discovered, which have aided considerably in the correlation of the strata with those of the mainland of East Africa.

Falkland Islands.—A geological survey of these islands was completed by Dr. H. A. Baker, and a report with map, sections and plates published. This survey extended the work done by geologists who had previously examined portions of the islands. Numerous additional fossils were discovered, and the close relations confirmed between certain formations of the islands and those of South Africa, as had been suggested by previous observers.

It should be stated that the minerals mentioned under the various Colonies and Malaya do not embrace all that have been found in them. There are many others that were known, and in some cases were being mined, before geological and mineralogical surveys were established—such, for instance, as alluvial tinstone in Nigeria and the Federated Malay States, gold in the Gold Coast, Tanganyika, and Nyasaland, and diamonds in British Guiana. The Surveys, however, can fairly claim to have done most useful work in these tinfields by their examinations and reports before the regions were effectively developed.

PROSPECTING PARTIES, OR A GEOLOGICAL SURVEY—A COMPARISON.

The view has been advanced that a Colony without a Geological Survey can derive so much benefit from the geological and mineralogical results contributed to it by prospecting parties attached to mining groups operating in the country, or independent of them, that a Geological Survey is unnecessary. Opinions will differ as to the correctness of this view. If that is correct it is so only as long as such mining groups or individuals supply this information. But, since it is much more common that such mineral results are carefully conserved for their own interests solely, no great amount of information would probably be received by the Colony. Besides, it is well known that prospecting parties of this kind are looking specially for certain kinds of minerals or metals, and the whole of their energies are devoted usually to the search, discovery and economic aspect of deposits of such minerals. No interest is taken usually in anything which has no important structural or economic bearing upon the objects of special search. Even respecting those there are possibly aspects of interest or value to the country, but not regarded as having any such to the groups. Thus much information of value is either not observed or recorded, or lost if obtained, and the country does not benefit fully.

Also, it sometimes happens that the operations of a private prospecting party are conducted with a view not to the discovery and legitimate exploitation of a promising deposit of a useful mineral, but to the successful flotation of a company, irrespective of its probable economic value.

As already indicated, the energies of ordinary prospecting parties of companies are not devoted to the search for numerous different minerals, so many such are probably passed unnoticed or untested, due to want of

knowledge, or of interest, or of both. Companies that exploit and develop their own discoveries, for example, gold or tin, do not usually take any active interest in, for instance, copper or lead. The development of such deposits to the metal-production stage involves a procedure entirely foreign to their activities and practice, and so their energies are directed solely to the metals which can be exploited more quickly and less expensively than those requiring smelting.

Further, the records of much of the work done by small mining companies and independent prospectors are not carefully recorded. Usually their operations are continued for only comparatively short times, and when discontinued there is often little to show for all the energy, time and money expended upon them.

In cases, however, where prospecting parties are under the direction of keen, capable geologists, interested in the numerous aspects of geology, and allowed by their principals to publish records of their observations, there is no doubt that much of interest and value to pure and economic geology will be the result, as has been shown recently in Northern Rhodesia. Such observers and the assistance rendered to Geology by them will be welcomed by Colonial Geological Surveys.

Moreover, is the argument valid that a permanent Geological Survey is unnecessary because there are in the country large numbers of prospecting and mining parties at work? Can it be said justifiably that an Agricultural Department is unnecessary in a country the natives of which are agriculturists and able to produce many products of the soil that are required for their food supply and possibly available for export? No, else why the establishment of such departments, and the great importance attached, and deservedly so, to their efforts? They are there to assist the natives to add to their list of products; to show them the best means to combat diseases of plants; to increase their production; to introduce improved methods of culture, and generally to raise their status as agriculturists. Why then should not the same principle and policy be applied to search for the rock, mineral and fuel wealth of the country, and if found, and of economic value, then to assist in its development? It seems but reasonable to concede the truth of this, and that being done it is time enough to consider the suspension or abandonment of the operations of such a survey if and when it has proved that the country does not possess such wealth. But there should be no time limit set to the proof or otherwise of this result. A country difficult to examine because of its natural features cannot be certainly expected to yield its mineral secrets, or confess its paucity of mineral deposits in the course of a few months, or even years of effort. Let it be borne steadfastly in mind that spectacular discoveries of valuable mineral deposits are not the only benefits that a geological survey can bestow upon a country, however important they may be, and however valuable may be their contributions to the revenue and prosperity of the country. There are many other ways in which such a survey can be of benefit to it, indirectly and directly. It has already been shown how this can be done in connection with the extension of railways and roads; the development of hydro-electric power; the discovery and supply of water for pipe-borne supplies for large centres of population; the construction of dams, wells and tanks for the scattered population of seasonally arid districts, and for the permanent and travelling stock; the

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advice to be given respecting the character and distribution of soils ; the utilisation of constructional stones ; limestone and its products ; brick and pottery clays ; formation of marine breakwaters ; silting and reclamation of lagoons and estuaries—a most important work for the future in some colonies—and prevention of coastal erosion.

Now for a consideration of the belief, and the assertion often expressed that the 'practical' man, and he alone, be he miner, prospector, water-diviner, or any other 'practical specialist,' and not the geologist, is the man who discovers deposits of minerals and supplies of underground water. Were we in the eighteenth century instead of the twentieth, with its great advance of scientific knowledge, such remarks might perhaps be justifiable, but who can honestly say that such is the case in nineteen hundred and twenty-nine ? We have evidence on every hand that the managements of large industries recognise the value of science and have their own laboratory staffs ; mining companies—whether of the precious or base metals, non-metallic minerals, coal, oil and gas—have permanent or consulting geologists attached to their staffs to advise upon the general and special geological conditions—mainly structural, petrological, mineralogical—and character of the ore-bodies, rocks, seams and wells. That being so, it is high time that this legacy from mediævalism was dispelled.

There is no desire to belittle the value and importance of the so-called 'practical man,' particularly the prospector with some knowledge of geology and the mode of occurrence of ore-deposits. It is well known that many valuable mineral deposits have been found by intelligent capable prospectors, men of keen observation, close reasoning and long experience, who thoroughly deserved their success. Similarly is it known that many others were the chance discoveries of novices who made no claim to the term of prospector, for with the proverbial 'luck of the beginner' they had been fortunate. All men conversant with the early history of mineral fields know numerous instances of this kind. But there are other prospectors, with more or less experience of searching for one particular kind of mineral, frequently gold or tinstone, and possessed of remarkable assurance, who, ignorant of the merest rudimentary knowledge of the origin and genetic relations of minerals generally, pose as prospectors of minerals of every description. They may be entirely ignored so far as their value as prospectors is concerned. Nevertheless, the capable prospector, unless possessed of a good geological knowledge of the origin, association and distribution of minerals, has his limitations, for usually he has restricted his operations to some one or two—perhaps more—kinds of minerals, usually gold alone, or gold and tinstone, or perhaps copper or diamonds. If he has experience of the mode of occurrence of these minerals in several countries under different conditions he is usually successful in proving a locality with respect to the presence or absence of any or all of these minerals. But otherwise, if the modes of occurrence in his new sphere of operations differ from those with which he was acquainted previously he may not detect the minerals there.

Two Gold Coast examples of this may be given. One prospector had sunk a shallow hole on the side of a hill, apparently for gold, and unearthed good manganese ore, but not recognising its identity, and probably regarding it as iron slag, apparently took no special notice of it. While the Director of the Geological Survey was surveying the Insuta manganese

ore deposit, after his discovery of it, he found this old hole, and noted that the prospector had failed to discover what later proved to be one of the largest and richest deposits of manganese ore in the world—one that was of great importance to the life of the British nation at a most critical period of the Great War, when sufficient supplies of high-grade manganese ore were unobtainable for the manufacture of effective munitions.

The other example is that of a prospector for gold, who had sunk a shaft, over 40 feet deep, through bauxite. He used the shaft constantly without knowing, until informed of that fact by the same geologist, that the material he had excavated was bauxite. In both cases the want of geological knowledge was the cause of the failure of the prospectors to recognize what they had excavated.

To Dr. E. O. Teale, Tanganyika ; Dr. R. C. Wilson, Nigeria ; Major N. R. Junner, M.C., Sierra Leone ; Dr. G. W. Grabham, Sudan ; Mr. E. J. Wayland, Uganda ; Dr. F. Dixey, C.B.E., Nyasaland ; Mr. J. B. Scrivenor, Federated Malay States, Directors of the existing Geological Surveys of Colonies and Protectorates, and to the Commissioner of Lands and Mines, British Guiana, I am indebted for the useful information they have kindly supplied regarding the operations of their Surveys. The value of the contributions of their Surveys to the well-being and advancement of their Colonies is evident from the results obtained. There is no doubt that as work progresses in areas not yet explored and detailed surveys are made in those already examined cursorily, many more valuable natural resources will be discovered by them.

My thanks are also tendered to Dr. C. A. Matley for the information furnished regarding Jamaica, to Mr. L. B. Ower for that respecting British Honduras, and to Mr. T. Crook, Principal of the Mineral Resources Department of the Imperial Institute, for some of that relating to several of the other Surveys.

In this address an attempt has been made to show the value of Geological Surveys to young countries, and the application of scientific knowledge and methods, both theoretical and practical, to the discovery of the valuable inorganic and organic resources of Nature, as opposed to the search for them in a more or less haphazard manner.

Though Geology has yielded much definite evidence of the genetic relations, associations and occurrences of minerals in rocks and lodes, yet discoveries from time to time have shown that some minerals have wider associations than had been known previously. It becomes necessary, therefore, to keep an open mind on many matters, to consider carefully all the evidence available, and not to be dogmatic in opinions and conclusions. Geology is not an exact science—therein lies much of its fascination—so, in the consideration of some of its aspects, uncertainty, imagination, and speculation must be tempered with keen and correct observation, sound reasoning and experience. Through the æons of the growth of our earth Nature has continuously added to the mineral secrets in her vast realm. Some of these secrets she herself has unveiled to man by her ceaseless variation ; others have been revealed by chance through the activities of man and animal ; and still others through the application of experience and science by man. To-day science plays the predominant rôle in these revelations, and is steadily forcing a recognition of this fact upon the peoples of the earth, for their common benefit.

SECTION D.—ZOOLOGY.

ADAPTATION.

ADDRESS BY

PROF. D. M. S. WATSON, M.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

MY predecessors in this chair in choosing the subjects of their addresses have set no fashion which helps me to determine on what subject to talk to you. Sometimes they have chosen to expound the details of that particular field of zoology in which they have themselves worked, sometimes they have discussed broad questions involving the fundamental assumptions of zoologists or speculated as to the beginnings of structures or of a phylum. When the section did me the honour to appoint me to this position I was naturally tempted to devote an hour to the discussion of those early reptiles which come from the Karroo system, animals which lie near to the base not only of the mammals but of all the important developments of the great class of reptiles.

But on consideration I decided to make use of my opportunity to discuss the significance of adaptation in animals.

The only great generalisation which has so far come from zoological studies is that of Evolution—the conception that the whole variety of animal life, and the system of interrelationships which exists between animals and their environment, both living and non-living, have arisen by gradual change from simpler or, at any rate, different conditions.

Evolution itself is accepted by zoologists not because it has been observed to occur or is supported by logically coherent arguments, but because it does fit all the facts of Taxonomy, of Palæontology, and of Geographical Distribution, and because no alternative explanation is credible.

But whilst the fact of evolution is accepted by every biologist the mode in which it has occurred and the mechanism by which it has been brought about are still disputable.

The only two 'theories of Evolution' which have gained any general currency, those of Lamarck and of Darwin, rest on a most insecure basis; the validity of the assumptions on which they rest has seldom been seriously examined, and they do not interest most of the younger zoologists. It is because I feel that recent advances in zoology have made possible a real investigation of these postulates that I am devoting my address to them.

Both Lamark and Darwin based their theories on the assumption that every structure in an animal had a definite use in the animal's daily life or at some stage of its life history. They understood by adaptation a change in the structure, and by implication also in the habits of an animal which rendered it better fitted to its "organic or inorganic conditions of life." Thus, for Darwin at any rate, a general increase in the efficiency of an animal was an adaptation. But amongst his followers the term came to imply a definite structural change of a part or parts by which an animal became better suited to some special and characteristic mode of life. The adaptation of flowers to ensure fertilisation by definite species of insects is a characteristic case. Such definite adaptations can only be shown to exist by very long continued observation of the animal under its natural conditions of life. In the post-Darwinian literature the suggestion that such and such a structure could be used for some definite function is too often regarded as evidence that in fact it is actually so used. My colleagues amongst the palæontologists are, I am afraid, offenders in this way.

But even if it can be shown that the structure of an animal is such that it is specially fitted for the life which it in fact pursues, it does not necessarily follow that this structure has arisen as a definite adaptation to such habits. It is always conceivable, and often probable, that after the structure had arisen casually the animal possessing it was driven to the appropriate mode of life.

The only cases in which we can be certain that adaptation in this true sense has occurred are those, unfortunately rare, in which we can trace in fossil material the history of a phylogenetic series, and at the same time establish that throughout the period of development of the adaptation its members lived under similar conditions.

It is not unusual for a student of fossils to discuss the habits of an extinct animal on the basis of a structural resemblance of its 'adaptive features' with those of a living animal and then to pass on to make use of his conclusions as if they were facts in the discussion of an evolutionary history or of the mode of origin of a series of sediments.

In extreme cases such evidence may be absolutely reliable: no man faced with an ichthyosaur so perfectly preserved that the outlines of its fins are visible can possibly doubt that it is an aquatic animal, and such a conclusion based on structure is supported by the entire absence of ichthyosaurs in continental deposits of appropriate ages and their abundance in marine beds. But if extremes give good evidence, ordinary cases are always disputable. For example, there is, so far as I know, not the least evidence in the post-cranial skeleton that the hippopotamus is aquatic: its limbs show no swimming modification whatsoever, and the dorsal position of the eyes would be a small point on which to base assumptions.

Most palæontologists believe that the dentition of a mammal, and by inference also that of a reptile or fish, is highly adaptive, that its character will be closely correlated with the animal's food, and that from it the habits of an extinct animal can be inferred with safety.

Here again the extreme cases are justified, the flesh-eating teeth of a cat and the grinding battery of the horse are clearly related to diet.

Crushing dentitions, with the modification of skull and jaw shape and of musculature which go with them, seem equally characteristic. I had always believed that the horny plates and the jaws of *Platypus* were adapted to hard food, and that that animal possessed them, whilst the closely allied *Echidna* was toothless, because it was aquatic and lived in rivers which might be expected to have a rich molluscan fauna which could serve as food. But the half-dozen specimens whose stomachs I have opened contained no molluscs whatsoever, and seem to have fed on insect larvæ, the ordinary soft bottom fauna of a stream. I do not know whether this is an accidental occurrence, dependent on a special abundance of insects in the Fish river in late spring, or whether it really represents the normal food. Nothing but continued observations made throughout the year can justify any statements about this case.

One of the very few animals whose food is adequately known is the herring, where the long-continued researches carried out as part of the international investigation of the North Sea have been based on the examination of thousands of stomachs taken throughout the year.

The mouth of the herring is clearly adapted to plankton, and indeed it does commonly live on such a diet. But some herring may be found stuffed with specimens of the bottom-living sand-eels, whilst Mr. Ford has shown me others which in youth contained nothing but *cheironomus* larvae. Thus even here, in the case of an animal with a very characteristic type of mouth, we should not be completely justified in assuming that we could predict its diet. How much less justified are we in drawing such conclusions in the case of less highly modified dentitions?

In the face of this uncertainty can we make use of the character of the dentition of fossil vertebrates for the determination of the nature of their food, and thus by building up phylogenetic series investigate the gradual development both of habit and their adaptation; one without the other is valueless. The classical case of the horse is, of course, familiar to everyone. From the time of Huxley the story of the gradual increase in depth of crown of the molar teeth and in the complexity of the pattern formed by the worn edge of the enamel which coats the cusps of the molars has been held to show a steady improvement in mechanism which enabled the *Equidæ* to take advantage of a wide extension of grass land which was assumed to have occurred in *Meiocene* times.

But this assumption in its ordinary form rests on the basis of an inadequate analysis of all the factors involved.

The modern horses are bigger than those of the *Eocene*: an ordinary hackney weighs about fifty times as much as *Eohippus venticolus*.

Thus, omitting from consideration the relatively greater heat loss of the smaller animal, which will be of importance only in a temperate climate, and also differences in basal metabolic rate resulting from other effects of size, the modern horse will wear away in a day fifty times as much tooth as its ancestor; but the surface area of its cheek teeth is only about fifteen times as great, so that without a deepening of the tooth crown by three and a third times it would have a shorter life.

Actually, the crown is deepened about thirteen times, so that its potential longevity is increased to about four times that of *Eohippus* on the assumption that the abrasive qualities of the food of the two animals

have not changed. Dr. Matthew has produced evidence to show that in *Merychippus*, the Miocene genus of horse, tooth change took place at a younger age than it does in modern horses; the implication being that the potential longevity was less than it now is.

Thus the fact that *Equus* has proportionately some four times as much tooth as *Eohippus* may mean no more than that it lives longer, and its marvellous dentition may not be adaptive in the sense that it is specially modified for the trituration of a new type of food. It may represent no more than a reaction to the requirements of a large animal.

Thus in its dentition the horse may show not a definite adaptation to a special diet, but such an improvement as enables a large animal to live longer than its small ancestor. I believe that most adaptations whose history can be traced in fossil material are of a similar kind. The changes which go on in the limbs of a horse do unquestionably result in the formation of a machine which is more efficient than that of the Eocene animal. In this case each leg is designed for rapid motion, the single toe is better fitted to stand the great stresses it receives than the three or four of earlier form, the interlocking of the third metapodial with three distal carpals or tarsals is clearly mechanically sounder than the old one to one relationship, and the reduction of the moment of inertia of the limb which results from the concentration of its muscles in the proximal half is a considerable improvement. How far these adaptations have resulted in an increased speed of galloping and how far they were necessary to enable an animal of much greater bulk to maintain the same speed we do not know, nor, unless a far more precise analysis of the whole mechanism prove possible, shall we ever know.

Whether a change which enables a mammal to become larger and to have a greater potential longevity is an adaptation may be disputed. Certainly it is very different from the usual conception of a structural change fitting an animal for a definite type of life under particular circumstances.

A large herbivorous animal of no higher speed than a small one suffers from certain disadvantages, of which the increased demand for food is the most obvious, which tend to offset the advantages it gains by the reduction of its surface area proportionately to its weight. It is difficult to show that it and its descendants will tend to be preserved by natural selection, relatively to somewhat smaller forms. The increased potential length of life and of the reproductive period is perhaps balanced by the longer immaturity within which it is probable that much of the racial mortality occurs. Thus the history of the horse which appears to provide an admirable case of steady adaptation of a phyletic line to a definite mode of life may perhaps show no more than the internal adaptations which are necessary to enable a large animal to function as well as, but no better than, its small ancestor.

There are, however, a few cases where we are, I think, on firmer ground. The slow and steady improvements in limb structure which go on in the mammal-like reptiles from Lower Permian to Lower Triassic times take place in animals which do not exhibit a steady increase in size, which indeed cover nearly the same range of sizes at the beginning and end of the story.

In the earliest of these animals the upper arm projected at right angles to the body, and the forearm lay at right angles to it, nearly parallel to the ground. The track was very wide, the stride absurdly short, and only one foot could be moved at a time, whilst some of the muscles were devoted entirely to the support of the weight of the body, leaving the whole propulsive force to be supplied by the remainder or rather by such of them as were not concerned with returning the limb to the position it occupied at the beginning of the stride. From these slow and clumsy ancestors we may trace the gradual acquirement of the structure found in *Cynognathus* or in a mammal; where the arm moves nearly parallel to the principal plane of the animal, the stride is greatly lengthened and every muscle contributes both to the support of the body and to its propulsion.

Here we have a case where we can observe an improvement of an animal mechanism which definitely enabled an animal to move faster than its ancestor.

But such general improvements in the mechanism of an animal's body, which are the only adaptations which can be proved to have occurred, differ so greatly in scale and in their general nature from that detailed fitting of an animal to some particular niche in its environment which Darwin believed to occur, that it is important to investigate whether there is any general occurrence of such special relationship of structure and habit and whether if it occurs it is rightly to be regarded as of adaptive origin.

It is, I believe, in the first part of such investigation that a good deal of the future value of physiological work in zoology lies.

The physiological work which is at present being conducted by zoologists falls under two main heads. It may be concerned with the explanation in physico-chemical terms of definite life processes, such as fertilisation or cleavage, the activities of cilia or the nature of muscular activity. Such work is of value to zoology because it increases our knowledge of the cell and all its parts and of the things which may control its activities. It will become essential for an understanding of the factors which underlie morphogenesis, that is of those factors some of which are carried as material bodies in the chromosomes. But it is clear that it will be long before even the fundamental phenomenon of cell division receives its explanation! Nevertheless, the present interest and ultimate value of such fundamental researches is certain; only through them can zoology ever hope to approach its ultimate aim, the explanation of the Animal Kingdom in terms of chemistry and physics, or the demonstration that such explanation can never be adequate. But few zoologists have a sufficiently wide knowledge of physics and chemistry to go far with them.

The other type of physiological work is that which, like the classical 'experimental physiology' of the medical school, is devoted to an attempt to understand the functioning of the different systems of organs and ultimately of the whole body of an animal.

I believe that such studies hold out the greatest promise of results of any in zoology. We do not know even as a first approximate the mode of working of the body of any one member of the majority of the phyla of the Animal Kingdom.

We know a good deal about what is called 'Human Physiology,' that

is the functioning of dogs and rabbits, with items from the frog. We know a little about the heart of a dogfish, and about its hæmoglobin, but nothing of its respiration or the activities of its nervous system.

Amongst the Mollusca we know a good deal about the food-collecting mechanism and digestive enzymes of Lamellibranchs, and even in some cases some details of the activities of the heart and the nature of their respiratory pigment. But in no single case do we know even the outlines of the whole physiology.

We do not know how much food is eaten or the relative proportions of proteins, fats, &c. We do not know how this food is utilised, how much to maintenance, how much to growth, and so on. We have no real knowledge of the function of excretion, we do not know the blood volume, nor the output of the heart under any circumstances whatsoever. We do not even know the oxygen-carrying power of the blood as a whole, nor the total consumption of oxygen and respiratory quotient in any one form.

Until these things are known, in at least a few individual species of each phylum, we shall not be in a position to understand the possibilities of adaptation which each fundamental type of morphology holds out and the real significance of the fitting of an animal to its environment.

The reason why such a series of investigations has not yet been carried out is clear; to do so implies a long-continued and perhaps tedious research involving the modification of many different physiological and biochemical techniques to enable them to be applied to new material; without holding out the bait of a promise of spectacular results. Far too much work in comparative physiology has been no more than the partial exploitation of a 'nice preparation' found perhaps by a casual observation.

But the ecological relationships of animals to their environments present many aspects which are now capable of investigation by simple physiological experiment. It would be a matter of extreme interest to know something about the amount of water required by two mammals, if possible members of different geographical races of the same species, or at any rate neighbouring species, one from an arid, the other from a more humid environment. To be valuable, such an experiment would have to be carried out under carefully controlled conditions of humidity and of temperature, and would necessarily involve an investigation of the variations in the composition of the urine under different conditions. Indeed this and all similar experiments would have to take into account that power of adjusting their activities to circumstances which all animals possess.

But water requirements, and their variation under different conditions of humidity, important though they probably are, are only one of the many things of which the effects of variations of mean temperature and range of temperature, proportion of the year in which the temperature falls below some point or exceeds some other, exposure to light, the chemical nature of the food supplies, the possible absence or insufficient amount of individual elements like phosphorus or iodine, are others which are obviously open to relatively simple experiment.

Only when such researches have been carried on for a number of pairs of animals shall we have any real understanding of the significance of the differences which separate one geographical race from another.

South Africa seems to me the country of all others which could provide the subjects for such an investigation.

But physiological work of the kind which I have suggested, although it will show to what extent there are variations between races and species of animals which fit them specially for life under definite physical environments, will not in general elucidate those morphological differences which alone are recognisable in a museum, and which have commonly been assumed to be of an adaptive nature.

That these structural differences are adaptive even in the sense that, no matter under what circumstances they arose, they do now in fact fit each form especially to its circumstances, is for the most part pure assumption. I do not know a single case in which it has been shown that the differences which separate two races of a mammalian species from one another have the slightest adaptive significance.

There is no branch of zoology in which assumption has played a greater or evidence a less part than in the study of such presumed adaptations.

The implication which lies behind any statement that such and such a structure is an adaptation, is that under the existing environmental conditions an individual possessing it has a greater chance of survival than one which has not.

Mr. G. C. Robson in his book 'The Species Problem,' which includes an invaluable summary of a widespread literature, could only refer to some eighteen papers in which an attempt was made to show by a definite statement of evidence that under natural conditions the death-rate of a population of animals is selective, sparing relatively those individuals which are distinguished from their fellows by the possession of definite structural peculiarities.

My predecessor, Prof. Weldon, a convinced Darwinian, judged rightly when he devoted many years to an investigation of this fundamental postulate of the theory of Natural Selection. A 'selective death-rate' is a term which clearly is only applicable to a population, it has no meaning when applied to an individual; thus any attempt to determine its incidence and the extent to which groups of individuals possessing definite characters are spared can only be carried out by a statistical method. But it is very difficult to discover cases in which it is possible to collect the data. Any investigation must show as a preliminary that the population considered is stable and that it is neither added to by immigration nor subject to emigration. The character of a sample must be determined, and in the nature of the case, if for example the character under investigation is the efficiency of a concealing coloration, the sampling error may be large and may be in the same direction as the divergence exhibited by that sample of the population which have died through some external cause.

Amongst the processes so far investigated only one seems likely to provide at all a general method. This is the study by Dr. Schmidt of Zoarces. He showed that the unborn young extracted from individuals of this fish living at the end of a long fiord did not differ significantly in any of the characters he observed, number of fin rays and of vertebræ for example, from adults taken some years later which could be regarded as having been born in the same season and place.

It is possible that a study of the history of a single-year class of a population of fish living in such an isolated environment as a lake, would yield very valuable information on the adaptive significance of some determinable variations. It is unfortunate that the extensive migrations of herring in the West European waters render the data accumulated by Fisheries Investigators unsuitable for the purpose.

The extraordinary lack of evidence to show that the incidence of death under natural conditions is controlled by small differences of the kind which separate species from one another or, what is the same thing from an observational point of view, by physiological differences correlated with such structural features, renders it difficult to appeal to natural selection as the main or indeed an important factor in bringing about the evolutionary changes which we know to have occurred.

It may be important, it may indeed be the principle which overrides all others; but at present its real existence as a phenomenon rests on an extremely slender basis.

The extreme difficulty of obtaining the necessary data for any quantitative estimation of the efficiency of natural selection makes it seem probable that this theory will be re-established, if it be so, by the collapse of alternative explanations which are more easily attacked by observation and experiment.

If so, it will present a parallel to the Theory of Evolution itself, a theory universally accepted, not because it can be proved by logically coherent evidence to be true, but because the only alternative, special creation, is clearly incredible.

The alternative explanations which are put forward of the existence of the differences which separate species from species or one geographical race from another are in essence three: either the difference is regarded as adaptive and its initiation and perfecting are attributed to a reaction of the animal which alters its structure in a favourable manner followed by an inheritance of the character so acquired, or, secondly, it is regarded as non-adaptive, or only accidentally of value, and held to have arisen by a change induced in the course of an individual development by the direct effect of some one or more environmental features, such change not necessarily being heritable in all cases. The third explanation is that the difference between one form and the other has arisen casually, isolation having enforced an inbreeding which led to the distribution of genes in different proportions in the two stocks.

The first alternative explanation suffers from the defect that the characters in question have not in general been shown to be adaptive, and that an inheritance of an acquired character of the kind required has not been shown to occur.

The second explanation, the direct influence of the environment, has the immense advantage that it is open to investigation by experimental methods, and suggests many attractive lines of work.

Here again experiments have been few. The most successful is that on the induction of melanism in moths by Heslop Harrison and Garrett.

By feeding caterpillars on food impregnated by salts of manganese or lead, these authors, in three independent series of experiments, obtained melanic individuals of a character which did not occur in the much larger

numbers of controls fed on untreated food, nor under natural conditions in the district of origin of the parent individuals.

Harrison and Garrett attribute the melanism which appeared under these conditions to the direct effect of the metallic salts, either on the soma or, as is perhaps more probable, on the germ cells.

They showed by a very adequate series of breeding experiments that the melanism which arose in this way is inherited as a simple Mendelian recessive. Although these experiments have not yet been repeated by other workers, there can be little doubt that their explanation is justified, and that they have for the first time brought about by artificial interference a new mutation, dependent no doubt on a change in a single definite gene.

But no one will pretend that this mutation in its visible form has arisen because it is valuable to the animal. Nor is there any evidence that it is correlated with physiological differences which render the animals which exhibit it less liable to be killed by feeding on contaminated food. There is no published evidence that such food results in a higher death-rate than that in the controls. Thus there is at least one case where there is very strong evidence that the environment may induce the formation of mutations which are heritable.

It is obvious that such a direct environmental effect, when taken in association with the completely established fact of the common occurrence of parallel or identical mutations in allied animals, provides a complete formal explanation of such facts as that the coat-colour of a race of a species of rodent from an arid region will in general be lighter in colour than that of a race from a more humid and therefore more thickly vegetated area. It is clear that such an explanation does not require that the coat-colour has any adaptive significance whatsoever: it is in complete contrast with the equally formally complete explanation by natural selection. But it has the advantage that it can be submitted to experimental confirmation.

The neo-Darwinian would explain this occurrence by assuming that the dark-coloured forms were less visible against the moist and therefore darker soil of the humid locality than lighter animals would be, and would thus escape the attacks of carnivores for a longer period. The light forms would escape notice under the bright illumination and glitter of an arid and especially a desert country. Such a view assumes without question that the colour of the two groups is heritable, though it makes no demands for any particular type of heredity.

The only experiments which have been made with geographical races of mammals are those which Sumner has carried on over many years.

Sumner began his work by collecting considerable numbers of individuals of a certain species of the deer-footed mouse *Peromyscus* from localities in California which present extreme variations in rainfall and temperature. He subjected each group to analysis, measuring such characters as the length of the tail and hind foot, and estimating the colour-coat by physical methods which allow of a numerical statement.

He thus showed that the mice from each locality varied, and that the distribution of the variates for each character formed a unimodal curve. He investigated by statistical methods the correlation between

pairs of the characters with which he worked, showing that for many of them the correlation was small. He showed that the curves for different subspecies might overlap, so that no one individual could fairly represent its race.

By a series of breeding experiments carried on with caged animals Sumner showed that, when allowance was made for certain bodily changes clearly caused by the artificial conditions of life, the races bred true in the sense that the modes of the curves of variation of the characters considered remained stationary.

The results of crossing individuals selected from different subspecies and treating in a biometric manner the offspring resulting from these crosses were uniform, in so much as that the *fi* generation were always intermediate in character between the parents, and the range of variation they exhibited was less than that of the parent stocks. In later generations there was no obvious segregation, and the range of variation increased again.

Sumner at first regarded these results as evidence of a blending inheritance without any Mendelian character; but subsequently concluded that they could be explained on a multiple factor hypothesis, like that which is accepted for Castle's hooded rats. The reduced variability of the *fi* generation is thus accounted for.

Although as a palæontologist who has seen the extraordinarily small magnitude of the steps which separate successive members of a phyletic line I am temperamentally indisposed to do so, I am forced to accept the multiple factor hypothesis as an account of the majority of cases of blending inheritance. Castle's experiments on hooded rats, carried as they have been over very many generations, seem conclusive for that particular case. It seems clear, furthermore, that any change in a spermatozoon which results in a change in the adult which arises from its conjugation with an egg, must be a chemical change; and chemical changes are all particulate, there are no intermediates between a hydrogen atom and a methyl group!

It follows therefore that the light-coloured mice of the arid interior of California differ from those of the coast because in them have been accumulated a number of genes for light pigmentation, much more sparsely present in the dark races.

Such a differential distribution of genes is of course what is assumed to occur under the influence of natural selection.

It is not perhaps very easy to believe that the direct action of the environment would result in the production of a series of mutations all independent, and all in the same direction, yet this assumption is necessary for the alternative explanation of direct environmental effect!

But Sumner went further, and attempted to investigate the possibility of such environmental influences by direct experiment. He transplanted a small colony of mice into a very different environment, enclosing them in a small netted area and leaving them to breed. The offspring which appeared during the course of the experiment showed no tendency to approach the local races in their characters.

This experiment has been criticised because the numbers of individuals were small, and because they were unnaturally crowded in a small en-

closure, and in other ways ; but it remains unique, the only attempt made with mammals to test this vital point.

Schmidt has, however, conducted a similar experiment with the viviparous blenny, *Zoarces viviparus*. This fish, which is a bottom-living animal supposed not to migrate extensively, forms a series of local races in the North Sea and the Danish waters. These are distinguished from one another by statistical differences of the curves representing the variation in the number of vertebrae, of fin rays in the pectoral fin, and of similar characters. These races appear to be stable. Their distribution in some areas such as the Roskilde Fiord shows a gradation along a line over which the salinity also changes, but the correlation so suggested between this environmental condition and structure breaks down when other regions are taken into account.

There is evidence derived statistically from the nature of the mothers that the variations are inherited, and an indication that, as in *Peromyscus*, the differences are not obviously Mendelian. Schmidt carried out transplantation experiments exactly parallel to those conducted by Sumner, and found, just as he did, that no direct environmental effect of the kind required was produced during the few generations he could investigate.

Thus here again we are faced with the fact that an apparent correlation of structure with the surrounding physical and chemical conditions exists, and that such evidence as there is does not confirm the view that this correlation has arisen directly. There remains as the only other alternative the view that the apparent correlation is illusory.

It may be accepted as a working hypothesis that the variable characters which separate one geographical race from another are produced under the influence of a number of genes, all independent, and all producing similar effects. As Prof. Karl Pearson pointed out in 1904, the effect of such multiple factors will be to produce an apparent blending inheritance ; a view now very generally accepted. It follows that, in certain cases at any rate, if a small group of individuals phenotypically similar, though genotypically different, differing from the norm of a population, be isolated and left to breed freely, they will, when considered as a population, tend to vary still more from the original mode in the population from which they sprang and that they will do so in the direction in which the original isolated group differed. Prof. Pearson has reached the same conclusion from his own very different standpoint and has evidence that the expected result does actually occur.

If then we can conceive of circumstances which will bring about such isolation in such a way that the individuals so separated are determined by an environmental condition, we shall have an explanation of the divergence of local races which will account for the appearance in them of individuals which lie outside the range of variation actually observed in the small samples of the parent races which have been investigated.

An explanation of this type accounts for some of the peculiarities which Sumner has noticed in *Peromyscus*. For example, the existence side by side of very light and very dark individuals in the same spot will present no difficulties, and the fact that there is no or very little correlation between such characters as colour, hind-foot length, tail length and width of tail

stripe will not be so surprising as it is on the theory of direct environmental influence.

But there do remain many obscure points: for example, Sumner in his cultures observed the appearance, either as mutations or more probably simply by segregation, of certain colour conditions which were inherited as simple single-factor Mendelian unit characters. These, a recessive Yellow, Albinism, &c., were not seen by him in the large collections of wild mice which he made, and as they occurred in comparatively large numbers in the cage-bred animals they should have done so. Is their absence due to a natural selection? or, if not, to what is it due? Thus we come back to the question of the existence of adaptation in the special form which is demanded by the Darwinian theory. And for such close and detailed correlation of structure with conditions of life we have as yet no evidence though much assumption.

There remains one type of adaptation which is perhaps of greater importance than those which we have been considering.

Perhaps the most striking of all the phenomena of life is the power which all animals and plants possess of so regulating their functioning, and when necessary their morphology, that their life is continued in equilibrium with the conditions under which they find themselves.

This adaptation is familiar in the automatic regulation of the action of the heart of a mammal and of its respiration to increased or decreased activity, and in the numberless similar adjustments of physiological processes.

Mr. Pantin tells me that his own experience has shown him that the physiological condition of marine animals is different in winter and summer, although I believe it has not yet been shown that this variation has an adaptive significance.

How far this adaptation to internal conditions is brought about by the same mechanism as adaptation to the environment I do not know. In those cases where the body fluid is nothing but sea water, as in echinoderms, it does seem evident that to a considerable extent internal and external environments are one.

But how far such physiological adaptations are of the same nature as those internal morphological adaptations which alter the relative sizes of parts in ways determined by geometrical considerations of squares and cubes, and produce analogous modifications in other structural features, there is no evidence. What is certain, however, is that these, which are the fundamental things in evolution, lie open to experiment.

Thus the present position of zoology is unsatisfactory; we know as surely as we ever shall that evolution has occurred. But we do not know how this evolution has been brought about. The data which we have accumulated are inadequate, not in quantity but in their character to allow us to determine which, if any, of the proposed explanations is a *vera causa*.

But it appears that the experimental method rightly used will in the end give us, if not the solution of our problem, at least the power of analysing it and isolating the various factors which enter into it.

SECTION E.—GEOGRAPHY.

NATIONAL SURVEYS.

ADDRESS BY
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IN these days Geography, like other sciences, has become highly specialised, and has many branches, each with its particular students. But the dictionary will tell you that the original meaning of the word 'geography' is 'earth-description,' and the fundamental conception of the science of geography is this idea of description of the earth's surface, and of the location of its various features. It is with this aspect of the science that I have been concerned for a good part of my life—the science and art of correctly locating and representing the features of the earth's surface—in other words, the business of surveying and mapping. I have, therefore, chosen this aspect of geography for the subject of my address, and I propose to talk to you about National Surveys. To avoid misunderstanding, I should make it clear that in speaking of survey I refer to land survey only, not marine survey. I shall first discuss the duties and functions for which, arguing from first principles, it appears to me that a National Survey ought to be responsible, and certain characteristics which I think such a survey should have. I shall then briefly describe the work of certain national surveys, both foreign and in the British Empire. Finally I shall endeavour to draw such lessons as are possible from this review of national surveys for our mutual benefit.

Every civilised country—I think without exception—has a National Survey; that is, a Survey Department, or in some cases more than one department, controlled by the Government. But when we come to inquire into their activities we find considerable differences in organisation and methods and in the actual duties allotted to these departments, and it becomes a matter of interest to inquire what are, or should be, the characteristics and functions of a National Survey.

On making such an inquiry one must clearly be mindful of the fact that the activities of a Survey Department must depend on the policy of the Government; in other words, that it is for every country to decide what survey work, like any other work, it requires. If a country decides, for example, after due consideration, that it requires very much less survey work done, and maps produced, than a neighbouring country, there is no more to be said by any outsider. At the same time, by studying the practice of nations, and by observing the advantages that arise as a result of an active survey policy, and the disadvantages that are the consequence of a lack of it, one may hope to arrive at a standard whereby one may judge of the efficiency of a country in this respect.

Now let us consider first what survey means—I use the word, of

course, for the purpose of this address solely in the geographical sense. It will, I think, be generally agreed that one of the main objects of a survey is the production of a map. It is not by any means the sole object. Much information of the greatest value can be conveyed adequately and conveniently without the aid of a map; such, for example, as the positions of trigonometrical points, which can be given by a list of co-ordinates, or the values of levels and bench-marks. But the bulk of the information obtained by the survey of a country is most conveniently and clearly shown by a map; and by general consensus of opinion the map is the outward and visible sign of survey work—the final result and fruition of that work.

The production of a map consists of a regular series of operations, each necessary to the whole; each preparing the way for the operation which follows, and each dependent on that which has gone before. These operations are first the establishment of the framework (usually but not always done by triangulation); next the detail survey on the ground; next the drawing of the map in the office; and next the reproduction and printing of that map. The first stage—the triangulation—produces the skeleton of the work. The second stage—the detail survey—provides the material for the map, clothes the skeleton, as it were. The third stage—the drawing—provides the map in the form we want it; but as it is still in the original, it is available only to the few. It is not till we reach the fourth stage, when the drawn map is reproduced and printed, that the results of the survey become available to the public for whom they are intended. We may say then that the function of a survey which is alive to its duties and which is provided with the necessary funds is to carry through all these stages of the survey of the country. But there is something further. Once a map is published it becomes out of date. The face of the country is constantly changing, and if the map is to remain a correct representation of the country, it must be kept up to date, or revised. We must then add this operation of revision to the functions of a properly conducted survey.

It may appear to you that in specifying these operations of survey I am merely reciting the obvious. You may well say, 'But surely no Survey Department would fail to carry through all these stages to their logical conclusion—no survey would stop at one of these stages, and not complete the work.' I can assure you, however, that it is by no means uncommon to find that surveys are not completed; that they do stop at one or other of the stages I have mentioned. I can give you many examples of this.

In this very country, in the Union of South Africa, you have an immense amount of most valuable triangulation which has been in existence for years; but little mapping has resulted. There has been no systematic progression from triangulation to survey, and from survey to the published map. In making this statement I should like to make it clear that I am not criticising anyone or any department—I am merely stating a fact which is common knowledge to those who are interested in these matters. Similarly I shall be able to give you examples, in countries whose surveys I shall describe to you shortly, of cases where the survey has reached the stage of the drawn map and never got any farther; the

map has never been published. And I shall give you other instances where the map once published has not been adequately kept up to date.

In dealing with the functions of a National Survey I have hitherto spoken of the production of 'the map.' But there is an infinite variety of maps; and before I go further it will be as well to be clear as to exactly what kinds of maps I have in mind.

Here we are again faced with the fact that every country must decide for itself what maps it requires. Because Great Britain publishes maps on seven different scales it does not follow that South Africa need do the same. The maps required by a country depend on local conditions and circumstances. It is clearly impossible to lay down any hard and fast rules, but we may perhaps arrive at some general principles. I have spoken of there being an infinite variety of maps, but they may be divided into different kinds and classes, and for our purpose it will be convenient to consider maps under two main headings, namely, cadastral and topographical.

The name 'cadastral' is derived from the French word 'cadastre,' the meaning of which the dictionary gives as a 'register of property.' But the French themselves in the 'Recueil des lois et instructions sur les contributions directes' give the meaning of the word as 'a plan from which the area of land may be computed and from which its revenue may be valued'; and it is in this rather broader sense that it is usual to define cadastral maps. The essence of a cadastral map is that one should be able to calculate areas accurately from it, and to define and show property boundaries; and this implies that such maps must show a good deal of detail, and be drawn on a large scale. While cadastral maps should, and usually do, show all the detail necessary for the purposes mentioned above, it is not uncommon to find that they omit certain other details which, though conspicuous on the ground, are not essential for the definition of property, etc.

The purpose of a topographical map, on the other hand, is to show the physical features of the country. These may of course be shown on any scale, and there is no reason why a cadastral map on the largest scale should not at the same time be a complete topographical map. But for various reasons—among others, economy and convenience—topographical maps are usually on smaller scales, and consequently omit certain details which cannot conveniently be shown on such scales, and which are not essential to showing the topography of a country. A topographical map must show all the general details and physical features of the country—rivers, roads, railways, buildings, forests, etc.—and it must also show the ground forms and general levels adequately. It need not necessarily show hedges and fences, and these and similar small details are often omitted owing to limitations of scale. A cadastral map, on the other hand, must show the small details such as hedges and fences, since these so often constitute property boundaries; but it need not show ground forms.

My own view is that it is the proper function of a National Survey to make adequate provision for maps of these two kinds, cadastral and topographical, because I consider them of such great importance to any community and any country for the following reasons.

One of the first problems that confront any community is the question of property, of land division and land tenure. From very early times it has been the custom in communities with any degree of civilisation to establish proof of ownership of land by a document of some sort, and this has usually been accompanied by, or has sometimes consisted solely of, a diagram or plan of the property. Each plan or diagram was produced solely for the purpose of showing the particular property in question, and usually without any reference to adjoining properties. In modern times the necessity has become apparent both for ensuring the accuracy of such plans, and for co-ordinating them; that is, for referring all to a common basis of fixed points.

Nearly every country has maps or plans of this sort, as they usually form the basis of the system of Land Registry in the country; and in many countries they are the basis of revenue from land taxation. In most cases the plans are isolated, in the sense that each represents a particular property, or village, or commune, and does not show detail outside. In some few cases these plans have been combined into a regular series of cadastral maps.

These cadastral maps or plans are obviously a most important feature in the mapping of a country; and it appears to me that it should be the function of the National Survey either to provide such maps or to control them. By control I mean that where, as is the case in some countries, it is the custom for cadastral plans to be prepared by private enterprise, it should be the duty of the National Survey to check such plans, to ensure their accuracy, and to see that they are properly related to the triangulation of the country; which is, and should be, the basis of all survey work. This system is, as many of you will no doubt know, that which is in actual operation in South Africa at the present time, due to the provisions of the recent Survey Act.

I have mentioned the isolated cadastral plan. This form of plan is common in the early stages of the development of a country, and is perhaps inevitable. But it should be only a temporary stage in the evolution of the survey of the country. As soon as it is practicable, it appears to me that these individual plans ought to be co-ordinated into a regular series of plans or maps; and that the National Survey ought to undertake this work. In other words, the National Survey should be responsible for the production of such cadastral maps, in a regular series of sheets, as the country requires.

The importance of these property or cadastral maps and plans will probably be readily admitted, since questions of property and land tenure appeal directly to most of us. The value of a good topographical map may not perhaps be so easily appreciated by those who have managed to get on quite well without such a thing. Yet the importance of having a good topographical map of a country—especially a country which is in an early stage of development—can hardly be over-estimated. It is of the utmost value to the settler, to engineers of every kind—road, railway and irrigation; to the geologist; and to the administrator. I will not dwell further on this subject at the moment; but I will return to it when I deal more particularly with the survey of South Africa.

We arrive then at the point that a properly organised Survey

Department ought to carry through all the survey operations that I have mentioned to their logical conclusion, and should produce or control the production of an adequate series of cadastral and topographical maps. But this does not complete the list of duties for which I think a National Survey should be responsible. There is one most important survey operation that I have not yet mentioned, and that is the question of levels, or vertical control. The triangulation of the country supplies the necessary horizontal control, and incidentally gives heights which are quite accurate enough for topographical purposes. But for scientific and for certain engineering purposes, an accurate system of levels throughout the country is a prime necessity. This can only be obtained by precise instrumental levelling; and as this is as much a survey operation as any other that I have mentioned it should in my opinion be carried out by the National Survey. It is so usually, but in some countries this work is done by an independent department; a procedure which seems to me unsound in principle. I include with levelling the allied question of determination of mean sea-levels and of tide-gauges.

There is another question which is so intimately connected with survey that it must be mentioned in discussing the functions of a National Survey; and that is the business of registering title deeds to property, which is called by various names in different countries—Land Registry, Land Survey, Deeds Office, etc. In some countries the Land Registry is a part of the Survey Office; in some it is independent, but works in co-operation and uses the National Survey maps as the basis for its work; in others it is not only independent in conducting its business but makes its own maps. Now opinions may differ as to whether the business of Land Registry should or should not be part of the National Survey; but there can, I think, be no two opinions as to the fundamental importance of the two offices working in the closest conjunction, and on the basis of the same maps, which should be those of the National Survey. If such co-operation is not practised, the result can only be friction and waste of effort.

This brings me to the last point that I would emphasise in connection with the question of National surveys; or perhaps it would be more correct to say to two aspects of the same point. I have dwelt on the importance of a survey carrying through to the end all the operations of its work; and this implies that the whole of these survey operations from start to finish should be under one and the same control. I do not believe, for example, in a survey carrying on its work as far as the drawing of the map, and then handing over to someone else to print. The dividing line between drawing and printing is so extremely difficult to define that such a procedure is to my mind both unsound and uneconomical. It may be necessary when a survey department is in an early stage of organisation and development; but as soon as it is practicable I am sure that it is sound for a survey to take over control of its own printing, as of every other stage of its work.

The second aspect of this point follows logically; it is that there should only be one survey authority in a country, and that the National Survey. This is a principle of obvious importance, but which has not

always been recognised in the past, and I shall be able to give you instances of divided authority, with the usual results of overlapping and waste.

Let me now recapitulate what appear to me should be the functions of a National Survey, and the duties for which I think it should be responsible.

1. The National Survey should be the sole survey authority in the country.

2. It should be under one control in all its operations, from the triangulation to the publication and sale of the map, and its revision.

3. It should be responsible for an accurate network of levels throughout the country.

4. It should produce, or control the production of, all cadastral maps.

5. It should produce, or control the production of, a good topographical map of the whole country.

6. Maps used for Land Registry or similar Government purposes should be the National Survey maps, or directly based on them.

7. All maps produced by or under the control of the National Survey should be reproduced and should be readily available to the public.

8. Adequate provision should be made for the revision of all maps.

Let us now take a look at some of the National Surveys of the world, and see to what extent they comply with, or differ from, the standard which I have laid down. For this purpose I propose to take some half a dozen countries in Europe; Egypt; The United States; and then various parts of the British Empire; concluding with Great Britain and the Union of South Africa. Time will permit of my dealing with these surveys only in the briefest and most general manner; but I shall try to give you a clear idea of their characteristics and functions.

In making this review there is one thing that strikes one forcibly, and that is that very few surveys indeed correspond at all closely with the model which I have described as in my opinion desirable for a National Survey. It is quite likely in fact that, after hearing about these surveys, you may, judging by the actual practice that obtains so largely throughout the world, think that I have been putting forward a counsel of perfection—something rather outside practical politics. I shall have something to say about that a little later; and I shall hope to convince you that my views on this subject are based on sound reasons, even though general practice does not agree with them.

Taking the surveys of Europe first, we find a strong likeness among them. They all, or nearly all, have certain characteristics in common. These are, first, that a military department¹ is responsible for all topographical mapping in the country; second, that such cadastral maps as exist are produced by an independent department; third, that it is very rare to find cadastral maps published. The view taken generally in Europe is that good topographical maps are a prime necessity for military purposes, hence the military character of their topographical surveys;

¹ In Germany the military department which was formerly responsible for topographical survey has now been replaced by a civil department, under the Ministry of the Interior.

that cadastral maps have no military value, and are chiefly required for revenue purposes; and that such cadastral maps are documents mainly for government use, or for occasional reference by the public, so that reproduction and publication are unnecessary.

As a result of these views we find that, generally speaking, European countries have good topographical maps. The commonest scale is 1:100,000 (about $\frac{2}{3}$ -inch to the mile), but there are variations, as, for example in France, which has a 1:80,000.² This map (called the General Staff Map) is printed in black only, the hills being shown by vertical hachures. The 1:100,000 maps of other nations are all published in colours, and in most cases hills are shown by contours.

In addition to the general maps referred to above, a good many countries have topographical maps on substantially larger scales. For example, in Germany a 1:25,000 map has been in preparation for a number of years, and is nearly completed, while a 1:50,000 is in progress. Italy has a 1:25,000 completed for populous areas, with a 1:50,000 for the remainder of the country. Belgium has a complete 1:20,000 and 1:40,000 for the whole country. Holland (which by the way publishes no 1:100,000) has a 1:25,000 and 1:50,000. France has begun a 1:50,000 map. These larger scale topographical maps are all published in colours (though in some cases there is also an edition in black only) and the hills are in all cases shown by contours.

All the countries mentioned have also general topographical maps on smaller scales, usually 1:120,000, published in colours.

Topographical maps in Europe are kept up to date more or less systematically; but they have not in all cases recovered yet from the interference due to the war.

It is interesting to note that the cadastral maps of Central and Western Europe were mostly started in the Napoleonic era. They are in all cases in charge of a cadastral or similar office under the Ministry of Finance. The usual characteristics of these cadastral plans are as follows. They commonly exist in manuscript only, a copy being preserved at each of certain centres (such for example as the headquarters of the commune and of the department). Each commune is the subject of a separate survey; they show most land divisions (such as hedges, fences, ditches, roads, rivers) but little or no other information. The scale is usually 1:2,500, but there are variations; and it is common to find 'tableaux d'assemblage' or index maps, for each commune, on a smaller scale such as 1:10,000, showing the various 'section plans.' These plans are available for inspection, and copies in manuscript can usually be obtained on payment.

In Italy and Germany we come for the first time to the idea of publishing the cadastral map. Italy has an old cadastral survey, varying very much in quality in different districts; but in 1886 a new survey was ordered, based on the triangulation of the Istituto Geografico. The normal scale in this survey is 1:2,000. Some of these new cadastral maps

² There is a French 1:100,000, but it is not the official military map. It was produced by the Ministry of the Interior mainly for the purpose of showing roads and railways; but it has now been taken over by the Service Geographique de l'Armée.

have been printed, but reproduction is not yet general. Judging from certain printed specimens seen, the published sheets are of uniform size, though the detail of the map is carried only to the boundaries of the commune and not to the sheet edge. Visible detail on the ground is shown, and every enclosure bears a number. No levels are shown. A criticism that we may make on these Italian cadastral plans is that no scale is shown on them, nor any reference to conventional signs or adjoining sheets. It is very satisfactory to see this recognition in Italy of the desirability of publishing cadastral maps, and the fact that this new cadastral survey is based on the general triangulation, and that the cadastral maps when available are used as the basis for 1:25,000 topographical maps, shows a degree of co-ordination and co-operation which is not met with often in Europe.

In Germany cadastral maps are for the most part regularly published and put on sale. The scale is usually 1:2,500, but varies. Those specimens that I have seen bear the appearance of being good and accurate surveys, and the style of drawing and reproduction is first class. On one old Prussian cadastral map I observed that figures denoting the area of each enclosure were given; but on the more modern version of the same map only identification numbers are given, and this seems to be the usual practice on all the German cadastral sheets seen.

The practice in Europe with regard to revising cadastral maps varies, but generally speaking it would seem that revision is neither systematic nor adequate. In France revision has been neglected almost entirely. In Italy the law of 1886 ordered that general revision was not to take place for thirty years at least, which shows that revision was not considered an important matter. In Wurtemberg revision is done by surveyors of the Taxing Department, whether adequately or not is not known. In Saxony it is done by private surveyors and is said to be unsatisfactory.

In certain countries in Europe—for example, France and Belgium—levelling is regarded as an independent operation and is carried on by another department.

In Europe then the practice seems to be (1) to have two departments, one responsible for topographical, the other for cadastral work; (2) in some cases to have a third department responsible for levelling; (3) to keep up to date and publish topographical maps; (4) with certain exceptions to maintain cadastral maps in original only; (5) to a large extent to neglect the revision of cadastral maps.

The Survey of Egypt has a wide reputation for excellence and efficiency, and it is fair to note that its organisation and development are due almost entirely to British control and supervision. In Egypt we find one Survey Department, responsible for all survey operations, including levelling. There is a complete series of topographical maps for the cultivated area—an old series on 1:50,000 scale, which is being gradually replaced by a new series on 1:100,000. (The reason for the adoption of the smaller scale is that the new series will have separate English and Arabic editions, whereas on the old the two languages were combined.) There is also a 1:25,000 topographical map. There is a complete old series of 1:2,500 cadastral maps, which will gradually be replaced by a new series on half the scale (1:5,000) with, in addition, 1:1,000 M.S. plans, which are not to

be published. There are also large scale town maps and street plans on 1:200 scale which are not printed. All maps are revised as occasion serves.

The Survey of Egypt carries out all first and second order levelling. It has, moreover, an excellent equipment for standardisation, scientific observations, etc. The Survey prints and publishes its own maps.

It will be seen that the Survey of Egypt complies closely with the standard which I have advocated for a National Survey.

On the other side of the Atlantic we find two great National Surveys which are of immediate interest to us : those of the United States and of the Dominion of Canada.

In the United States we have a country of great extent, but at the same time of great wealth ; a country, moreover, which has a reputation for efficiency and for being in the forefront of economic progress. It is, therefore, of the greatest interest to our inquiry to see what form their survey takes, how it is organised, and what is its state of progress.

We find in the first place that there is no one survey department which is responsible for all survey operations. The Coast and Geodetic Survey (a bureau of the Department of Commerce) produces coastal charts, with such small amount of topographic work along the coast as is necessary for these, and does first and second order triangulation, traverse, and levelling, and allied scientific work. The Geological Survey (a bureau of the Department of the Interior) carries out its own third order control, both horizontal and vertical, and produces and publishes topographical maps on four scales, besides smaller scale wall maps, etc., and in addition to geological and allied work. The Geological Survey is in fact the topographical survey of the United States. Such an arrangement seems peculiar to us, in Great Britain at any rate, since we have been accustomed to regard topography and geology as distinct sciences ; but in the United States geological and topographical work have from the earliest times been carried on together.

The topographical maps published are on scales of approximately $\frac{1}{4}$, $\frac{1}{2}$, 1 and 2 inches to the mile. The Geological Survey prints and publishes its own maps. There is no definite system of revision in operation at present, it being considered that completion of the original survey is the first duty to be carried out ; but some revision has been done in specific cases.

The General Land Office (Department of the Interior), is charged with the cadastral surveys of public lands—i.e. United States territory, except the original thirteen States, which presumably do their own surveys. Cadastral surveys were started about 1785 ; and consist mainly in surveying and dividing land into rectangular blocks of six miles square, subdivided into sections of one mile square. The work is complete for most of the country and revision is being done in many parts. The plans (or 'plats' as they are called) are printed and on sale. It is important, however, to note that the main business of this survey is to mark divisions *on the ground* ; and that the plats are of value only to indicate graphically the land sub-divisions and their dimensions, and to give a rough idea of their physical features. They show no elevations, and are of no value as topographic maps. These plats cannot be considered as cadastral plans in the sense that we understand them.

This office also issues various small scale maps of the whole United States, and of various individual states.

The work of all the above departments is co-ordinated by the Federal Board of Surveys and Maps, which is composed of representatives from fourteen Federal organisations. The Board acts as an advisory body and has done most useful work in preventing duplication and overlapping and in securing uniformity in scales, symbols, etc.

With Canada we begin our consideration of the surveys of the British Empire. The organisation in Canada has this in common with that of the neighbouring United States, that there are several Survey Departments each responsible for certain branches of work; with a 'Surveys Bureau' to co-ordinate the work. The situation in Canada is, indeed, rather complicated and not easy to follow. At the outset we have to recognise the difference between Provincial Lands and Dominion Lands. Each province has its own survey organisation, concerned mainly or entirely with land or cadastral surveys. The Dominion has an independent organisation, responsible for Dominion Lands. The Dominion Survey is divided into three branches: the Geodetic Survey (under a Director), the Topographical Survey (under the Surveyor-General), and the International Boundary Survey. The work of these branches is co-ordinated by a Surveys Bureau, at the head of which is the Director-General of Surveys. The Geodetic Survey is responsible for triangulation and levelling; while the Topographical Survey is responsible, besides topographical work, for land, control, land classification, and aerial surveys. But in addition to these we find the Department of National Defence and the Geological Survey, both of which are producing topographical maps. The triangulation and levelling work done by the Geodetic Survey is of a high order; while the Topographical Survey are producing excellent topographical maps. The scales adopted are one, two, and four miles to the inch, according to circumstances, and it is intended eventually to cover the whole country with this National Topographic series.

Besides topographical work, the Topographical Survey carries out cadastral work in its Land Surveys branch. These surveys based, like those of the United States, on six miles square townships, and similar in nature, are being carried on systematically, and an immense amount of work has been done.

It will be remembered that Canada (owing mainly to the late Dr. Deville, Surveyor-General) has taken the lead in photographic methods of surveying. The country is particularly suitable for this method, and the great progress made is due largely to its adoption.

It may fairly be said that Canada is showing a fine example in carrying out systematic surveys of her territories, surveys geodetic, topographical and cadastral. At the same time I do not think that the organisation of surveys in Canada or in the United States is one to be copied. It is fairly obvious, I think, that there has been in the past a great deal of independent and unco-ordinated effort in both countries and that the present situation, while no doubt working well practically, is a compromise; and the suggestive and advisory functions of a Board can never, in my opinion, take the place of the personal control of a Director.

The Survey of India has deservedly a world-wide reputation. It is a highly organised and admirable survey, which in its geodetic and other scientific work can bear comparison with any other in the world. On the mapping side its activities are, however, confined solely to topographical work. The Survey of India produces maps on the scales of 1-inch, $\frac{1}{2}$ -inch and $\frac{1}{4}$ -inch to the mile, as well as various smaller scales. Revision of these topographical maps is contemplated, but exists more in theory than in practice. The Survey prints and publishes its own maps.

Cadastral work in India is done on a provincial basis. A native official called the patwari of each village is responsible for keeping up to date a map of his village, with its property boundaries. In some provinces the technical part of these surveys is done under an officer lent by the Survey of India.

Ceylon has a first-rate Survey, which is responsible for all operations; and the same applies to the Federated Malay States Survey. Similarly, most of the African Colonies and Protectorates have a single survey authority, responsible for all survey work in the country. Examples are the Gold Coast, Nigeria, and Uganda, in which, although the survey is in an early stage and much territory remains to be done, the organisation and the programme of work are complete and comprehensive, and often include schools of training for natives, and full equipment for reproducing and printing their own maps. On the other hand, we get Nyasaland, with a 'Lands Officer' and a negligible staff; and Northern Rhodesia, where a very small staff is wholly occupied with cadastral work, and has neither the means nor the opportunity to undertake much-needed trigonometrical and topographical work.

In both Australia and New Zealand a great deal of cadastral work is done, in the form of surveys of property and lands, frequently isolated; but in neither country is there, so far as my information goes, any system of cadastral survey organised on the lines we have been considering.

New Zealand has a few topographical maps, mainly of manœuvre areas, produced under the military department. In Australia topographical maps are, according to my information, almost completely lacking. New South Wales has a triangulation of the highest class, and a certain amount exists in other states. Proposals have been made for carrying out a geodetic survey of the whole of the States under Federal arrangements; but these proposals contemplated only the establishment of first and second order triangulation, and as far as I am aware did not even entertain the idea of carrying the work through to the stage of mapping.

I will now give a short account of the Ordnance Survey of Great Britain,³ following it with some remarks on the survey situation in the Dominion of South Africa.

The Ordnance Survey began its work as a properly constituted survey

³ The Ordnance Survey used to be 'of Great Britain and Ireland'; but since the establishment of the Irish Free State the surveys of that State and of Northern Ireland have been independent. The description given applies, however, equally to the maps of Ireland as to those of Great Britain.

in 1791; it is therefore, to the best of my belief, the oldest organised survey in the world. The survey is a singularly complete one. A wide range of maps is published, extending from the cadastral maps on the 1:2,500 scale (25 inches to the mile) to the 6-inch, 1-inch, $\frac{1}{2}$ -inch and $\frac{1}{4}$ -inch to the mile, as well as larger town plans and smaller scale wall maps. With the exception of the 25-inch, which does not extend over open moorland areas, the whole of the British Isles is completely mapped on all these scales, and the sheets of every series are printed, published, and on sale. But a possibly more noteworthy feature of the Ordnance Survey is that all its maps from the largest to the smallest scale are the result of accurate survey rigidly based on the triangulation of the country. There is only one survey authority in Great Britain; and every map is based ultimately on the 25-inch map.

The Ordnance Survey topographical maps of 1-inch to the mile and smaller scales are all published in colours. On the ordinary edition of the 1-inch, hills are shown by contours, but in certain special sheets layer colouring and hill shading are added. On the $\frac{1}{2}$ -inch and $\frac{1}{4}$ -inch scales layer colouring is used. The 6-inch map is printed in black with red contours; the 25-inch in black only. The characteristics of the 25-inch—the cadastral map of Great Britain—are that all topographical features are shown; every enclosure is numbered, and the area is given in acres and decimals; all civil division boundaries are shown, and also the positions and heights of bench-marks and spot heights. An interesting feature of all Ordnance Survey maps also is that the position and nature of all antiquities are shown; that is, of ancient ruins, earthworks, barrows, tumuli, and other objects of archæological interest. On the 25-inch these are shown in great detail; on other maps according to the limitations of scale. There is a regular system of revision for all maps, except the town plans which are not now maintained. Large scale maps are revised every twenty years; small scale every fifteen.

The Ordnance Survey is responsible for levelling, as for all other survey operations. There is a complete system of levelling throughout the country, with permanently marked bench-marks.

In England the Land Registry Office is independent of the Ordnance

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PAGE 110. The statement that topographical maps are almost completely lacking in Australia is misleading. Forty-five sheets of a one-inch survey have been published or are in course of publication. These cover some 23,000 square miles in the vicinity of the five larger towns, and are of good quality. It is regretted that this series was overlooked when the statement was made.

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In England the Land Registry Office is independent of the Ordnance Survey, but the Ordnance Survey maps are used for the registration documents. For Land Registry work frequent additions and alterations to the map are required, and for this work the Land Registry has a staff of surveyors and draftsmen. There was obvious danger that in course of time the Land Registry maps might depart considerably from the Ordnance Survey original; and there was further the waste of effort entailed by Land Registry surveyors carrying out revisions which must eventually be done also by the Ordnance Survey surveyors. Arrangements have consequently been made now whereby the Ordnance Survey will gradually take over the revision work necessary for Land Registry purposes.

This analysis of National Surveys has necessarily been very brief, and is obviously incomplete, as time does not allow of my dealing with all surveys. But it has perhaps served to give a general idea of how surveys

are organised throughout the world. What deductions can we make from it ?

In my statement of the form that I think the ideal National Survey should take, I laid great stress on the desirability of unity of control of all forms of survey. I said I thought that there should be only one survey authority in a country, and that there should be a single control of all survey operations from start to finish. Perhaps the chief point that strikes one in analysing the organisation of National Surveys is the lack of such unity. If we except the Ordnance Survey and the Survey of Egypt, and certain British colonial surveys, such unity of control is conspicuous by its absence ; and one of the most characteristic features of foreign surveys is the almost complete divorce of cadastral from topographical work. They seem to be commonly regarded as things apart. The idea of a single department responsible for all forms of survey appears to be a British idea, as it is only in countries of British nationality or controlled by British that it is found. In fact, it might almost seem that in stating what I believe to be the sound and ideal form of organisation for a National Survey I was merely quoting the practice of the Ordnance Survey. But that is not so. I do not argue that the organisation that I advocate is right merely because it is that of the Ordnance Survey, but because it seems to me absolutely sound and defensible arguing from first principles. The British people have an extraordinary faculty for getting practical things done, and in the end often done well ; but logical and orderly thinking out and arrangement is the last quality I would claim for them as a race. Yet it does seem to me that in survey matters the British have developed eminently logical and sound ideas and have put them most beneficially into practice.

All surveyors will agree that the idea that there is any essential difference between a cadastral and a topographical map is absurd ; the difference is merely one of degree and not of kind. It seems therefore logical to argue that both should be produced and maintained by the surveyor. Indeed one may put it more strongly, for it is obviously wasteful to send one party into the field to produce one kind of map, and another to produce another kind, when one good map would serve as a basis for all kinds. In Europe the so-called cadastral maps are regarded much less as maps than as diagrams and documents necessary for the purpose of supervising revenue. They have become to a large extent the documents of a financial department. The question obviously arises whether the countries in question have suffered from this policy. If the argument that all survey should be under one direction is sound, one should be able to show that some disadvantage has resulted where this rule has not been followed. Can this be shown ? Let us take France as a typical example.

France has a cadastral survey, on a large scale—usually 1:2,500—made on the average about a hundred years ago. As far as one can judge—and we had opportunities for doing so during the war—this survey, though not based on any triangulation, was a reasonably accurate one. It has been left practically untouched since. The manuscript plans that one may see on application in the Mairie of any commune show the country as it was in the time of Napoleon.

This survey must have cost a lot of money to carry out, and the map

when produced must have been of great value to the country. Owing to lack of revision the value of that map to the country has steadily deteriorated until now, when it must be widely negligible. I cannot believe that if this map had been in charge of a surveyor it would have been allowed to deteriorate in this way. I cannot believe that he would not have maintained it and made as accurate a map as possible. I am obviously unable to prove this, but I think that all surveyors will agree with me that if a surveyor had been made definitely responsible for that map he would have looked after it.

It appears to me, therefore, that France has definitely suffered from allowing this once valuable map to remain in charge of a purely fiscal department.

Take the question of publication. To survey and map any country is an expensive business; and it is particularly expensive to carry out a cadastral survey, presuming that it is a reasonably accurate survey, on account of its large scale and the great amount of detail that has to be mapped. Now the cost of reproducing and printing such maps is almost infinitesimal compared with the cost of surveying them; and it seems to me a penny wise and pound foolish policy to refrain from the small extra expense that would be entailed by publication. The maps embody a large amount of information of value to the public, and obtained at public expense. It seems only reasonable, therefore, that this information should be made available to the public.

Human activities take very similar forms all the world over, though there may be superficial differences. Since the world began men have bought and sold houses, estates, lands; and a usual accompaniment of such sales is a map or plan. In England, where accurate 25-inch plans exist for all cultivated and inhabited country, it is easy to obtain such a plan. In France, where the once good plans no longer have any value, they must be made afresh. Here again I think we may say that France has suffered through not carrying through her survey policy to its logical conclusion.

Another point that may be mentioned is the question of military value. European countries assumed prior to the Great War that cadastral maps were of no military value. As the war went on, the demand grew for maps of larger and larger scale. England was no wiser in this respect; but she was much wiser in her survey policy. Had the war occurred in England it would have been an easy matter to supply maps of any scale required. In France how often must the armies have wished that good, accurate large-scale maps were available! As it was, we had to make those maps ourselves. We used the hundred-year-old French cadastrals, and were very glad to have them; but how enormously their value would have been enhanced had they been modern, up-to-date maps!

The conclusion seems justified that France has suffered definite disadvantages owing to her policy of letting her cadastral maps become mere documents of a financial department, and of not carrying out her survey to its complete and logical end; and the same conclusion will apply to other countries in a similar situation.

In the U.S.A. and in Canada division of responsibility of another kind used to exist. The disadvantages of such a state of things and the need for unity of control was felt, and has been met, as I have related, by the estab-

lishment of Survey Boards. I believe that the existing system works well and without friction, but I believe also that this is due mainly to the common sense and goodwill of the men working it, rather than to any advantages in the system.

What is the survey situation in South Africa at present? In January 1921 a Survey Commission was appointed, and in July of the same year it issued a Report. This was not by any means the first report on survey questions in this country that has been made; nor was this Commission the only one that has investigated the subject; but as it is the latest, and the only one on whose recommendations action has been taken, we may confine our attention to it. The Report of this Commission is a most admirable document; and if I quote from it my excuse must be that Government documents are seldom read except by the few who are professionally and immediately interested. The Commission drew attention to the great waste that resulted to the country in the absence of a scientific system of carrying out cadastral surveys; it pointed out the need for greater co-ordination and unity of control in survey matters; and it dwelt very strongly and forcibly on the great need for a good topographical map of the country. The Commission made a large number of recommendations, all in the direction of securing greater unity and more reliability and scientific precision in the surveys of the country, and of making the survey more complete and comprehensive. As a consequence of this Report in 1927 a Survey Act was passed, which gave effect to most of the recommendations of the Commission, though not to all.

As a result of this Act, survey in South Africa is unquestionably in a very much sounder position than it has ever been before. The present organisation is that there is a Director of Trigonometrical Survey, who is responsible 'for such trigonometrical, topographical, level, and tide surveys . . . etc., as the Minister may direct'; while in each province there is a Surveyor-General who is responsible for controlling cadastral work in his province, and also, be it noted, 'for conducting when required by the Minister a general triangulation and topographical survey of any portion of the Union.' As a matter of actual fact, the Director of Trigonometrical Survey has been charged with the duty of carrying out a topographical survey, and no Surveyor-General of a province has as yet, so far as I know, been entrusted with this duty. The Commission recommended the appointment of a Director-General of Surveys. The Act does not carry out this recommendation; but it establishes a Survey Board 'for the purpose of promoting and controlling all matters' affecting survey; and it empowers the Governor-General, if he think fit, to appoint a Director-General of Surveys, to whom the Minister 'may . . . assign the functions of the Survey Board.' The Act also establishes a 'Survey Regulations Board' for the purpose of making regulations for survey practice and securing uniformity.

It would seem, therefore, that the Act recognises the need for unity of control, but provides it for the present by a 'Survey Board,' which consists of the four Surveyors-General and the Director of the Trigonometrical Survey; and provides also for the possibility of replacing the Survey Board by a Director-General.

These measures do not go so far as the Survey Commission recommended ; but they undoubtedly constitute a great step forward in securing unity of control and uniformity of practice.

The situation with regard to cadastral surveys in the Dominion is difficult. A vast amount of surveys of farms and properties has been done, and exists stored in various archives. It varies largely in quality, but includes much most valuable material. But it is most difficult of access, and it has long been felt by the thinking surveyors of this country that more use should be made of it. The subject has been ably dealt with in an article in the *Survey Journal* for March 1924 by Mr. Whittingdale, who argues that it should be collected, co-ordinated, and plotted in the form of a regular series of cadastral plans. Whether such a work would be practicable I am not competent to say, though it is interesting to note in the same article that experimental cadastral plans, presumably made in the suggested way, have already been constructed in the office of the Surveyor-General, Cape Town. But of its desirability I have no doubt whatever. It is, to my mind, and as I have attempted to show in this paper, a cardinal principle that survey work that is done should be published and made available ; otherwise it is largely wasted ; and the preparation of a series of uniform cadastral plans of the Dominion should, I think, take a high place in the Survey programme. It should not be forgotten, of course, that certain compilations of the existing farm surveys have been made in the Transvaal, Orange Free State, and Natal, but these do not quite meet the want.

The Survey Commission did not touch on the question of a regular cadastral map, but it devoted a substantial part of its Report to the subject of topographical survey. South Africa is at present singularly deficient in good topographical maps, and there is, I think, little doubt that they are a crying need. The need for such a survey has been consistently advocated for many years past ; and it is difficult to add anything of value to the arguments which have already so often been put forward. My excuse for speaking at all on the subject is that public apathy in the matter is so great that it is only by constant reiteration that one may entertain a faint hope that at some time a little interest may be aroused.

I am going to give you two short extracts from statements made by others which put the question clearly and forcibly.

The first is by a Director of Irrigation in South Africa, and was quoted in the Survey Commission's Report.

'The need for an accurate topographical contoured survey is felt almost daily by services such as irrigation, roads and bridges, railways, and agriculture. Hundreds of thousands of pounds would be saved in a few years to these services if reasonably accurate topographical maps existed.'

The next is from a statement prepared by the United States Geological Survey, on the need for expediting the topographic mapping of the United States.

'Topographic maps . . . serve as a base on which most problems affecting human activities may be studied and investigated and plans made for their solution. The lack of topographical maps in any area retards the development of that area and increases the expense of planning

public works. The possession of such maps insures the economical planning of improvements and reveals possibilities for the development of resources that otherwise would remain unknown.'

The Survey Commission stated that in South Africa a topographical survey is particularly necessary from the geographical circumstances of the country. It pointed out that, in the absence of waterways, roads and railways must be laid down before a country can begin to progress; and further that irrigation and conservation of water will play a great part in the development of the land. It then stated that a necessary preliminary to undertaking any schemes of the nature mentioned was a knowledge of the topography, and that a good topographical map would save enormous sums that are continually being spent in reconnaissance, and would obviate a great amount of wasted effort. To this weighty statement we might add the enormous value of a good topographical map to all who are concerned in the government and administration of the country.

Another reason which makes the need of a topographical map of first importance is the question of geological survey. Geological information is deprived of a great part of its value until it is correctly plotted on a reliable map. Perhaps the best example and proof of this is the case of the Geological Survey of the United States. In that rapidly developing country it was felt that geological survey must be pushed on as fast as possible. The geologists found, however, that they must have good topographical maps; and there being none in existence, they set out to make them; with the result that, as I stated earlier in this paper, the Geological Survey of the United States includes the Topographical Survey. In South Africa the same considerations apply with peculiar force; and it seems incredible in a country where geological survey and mineral development has such possibilities, that the value of a topographical map should have been so long ignored.

Numerous instances could be given of the savings that result from the establishment of a good topographical survey early in the history of a country, and of the losses that are consequent on the lack of such a survey.

Some of the most illuminating examples are those connected with railway construction. The Report of the Commission gives two cases taken from Nigeria, in the first of which for lack of reliable topographical knowledge the Lagos-Kano line was badly laid out, and enormous sums of money were subsequently expended on reconstruction to improve the line and lessen the running expenses. The waste in such a case, as the Report points out, includes not only the cost of the necessary reconstruction, but the greatly enhanced cost of running trains on the original bad line with its unnecessary curves and gradients.

In the second case a topographical survey was made before the railway was located, and it is stated that the result fully justified all expectations, and that the chief engineer was able to report that he was in consequence enabled to complete his reconnaissance work in record time and to discover routes through difficult forest and hill country that would otherwise have been unobtainable.

When the Uganda railway was constructed the lack of a topographical

survey had similar unfortunate results. Forty miles of the line had to be reconstructed, at a cost which, for construction alone, would have provided an adequate survey of a large portion of Kenya Colony.

The present situation with regard to topography in the Dominion is as follows: There is a good topographical survey (1:125,000 scale) of the Orange Free State, with an extension for a short way into the Transvaal. There is a 1:250,000 survey of Basutoland and of the northern part of the Cape Province. The latter is classed as a 'reconnaissance' survey; it is useful, but in Cape Colony at any rate hardly adequate to the needs of the Dominion. Of the remainder—about half of the Cape Province, almost the whole of Natal and the great bulk of the Transvaal—no topographical map exists. It will be seen that a vast amount remains to be done in the way of topography.

It is true that a start has been made with topographical survey of the country. The Director of the Trigonometrical Survey has been charged with this duty, and a sum of money has been allotted for it. The sum seems to an outsider, considering the immense amount of work which has to be done, to be extraordinarily small. It is something that the principle has been recognised, but no adequate progress will be made until a much larger sum is allotted. The question is also bound up to a large extent with that of staff. So far as I am aware the Director of Trigonometrical Survey has no permanent staff for field work, and very little for work in the office. This is to be regretted. In my view a Government Survey ought to have a regular permanent staff; otherwise it is liable to have fluctuations in the quality and quantity of its work which are most undesirable. It may of course be convenient, and usually is in the early stages of a survey, to have in addition a certain number on a temporary basis. The same observations apply to the staffs of the Surveyors-General. In all cases there should in my opinion be a staff of permanent Government employees. All experience goes to support this view. The example of Canada may be quoted. Cadastral surveys there used to be put out to contract, but this was dropped in 1915 and I am informed that all surveyors are now Civil Servants. It is to be noted that the Survey Commission laid particular stress on this point, especially in the case of the trigonometrical and topographical surveys.

The most satisfactory feature in South African survey is perhaps the triangulation; it is all of good quality, and is being pushed on as fast as funds will allow; but there is undoubtedly a great need of extension in the second and particularly in the third order triangulation. Some levelling has been done, but nothing as yet in the way of closed circuits; so that levels are at present, to use a common expression, hanging in the air. All surveyors know that it is impossible to check the accuracy of any levelling, and to distribute the errors, until the work has been closed on the starting point.

South Africa has a great survey tradition behind it. Some of the greatest survey schemes were started in this country; some of the finest survey work in the world has been done in it; and some of the best surveyors of the Empire have been trained here. South Africa ought not to be content to lag behind other nations in this matter. She ought

to be in the van, setting an example to others. I would like to see a complete and united Survey of South Africa, with its triangulation carried all over the country to the third order; with a complete network of levels, primary, secondary, and tertiary; with a good series of topographical maps and cadastral maps; and I would like to see the Survey printing and publishing all these maps itself. You may say that this means money, and that it is a matter for Parliament. Peoples are in the habit of blaming Parliaments; but I am not at all sure that it is always Parliament that is to blame. If the people of South Africa take a real interest in this matter, and demand an adequate survey and good maps, Parliament will find the money. I commend this ideal to the people of South Africa, that they should be determined to have a National Survey adequate to their place among the nations, and worthy of their history and great traditions.

THE PUBLIC REGULATION OF WAGES IN GREAT BRITAIN.

ADDRESS BY
PROF. HENRY CLAY,
PRESIDENT OF THE SECTION.

I.

A GREAT change has taken place during the last twenty years in the methods of negotiating wage-changes. In 1910, when the Labour Department of the Board of Trade published the result of an inquiry into collective agreements, it was estimated that 2,400,000 workpeople worked under conditions specifically regulated by such agreements. The report adds—and the addition is important—that there were a large number of other workpeople whose wages, hours of labour, and other conditions followed, and were in effect governed by these agreements; but a generous allowance for this addition will still leave the total far short of the wage-earning population, which, excluding domestic servants as outside the probable field of collective bargaining, numbered about thirteen millions.

Trade unionism was, however, spreading. In 1914 the total membership, which at the time of the inquiry was $2\frac{1}{2}$ millions, had grown to over four millions. It reached a peak of $8\frac{1}{3}$ millions in 1920, and was still 4,908,000 in 1927, the latest year for which returns are available. More significant in principle than this expansion of an existing instrument of control was the direct intervention of the State in the fixing of wages by the Trade Boards (Minimum Wage) Act of 1909. Confined at first to trades in which wages were 'exceptionally low,' this Act made the settlement of minimum rates of wages by a representative joint body compulsory, associated with the representatives of the workpeople and employers impartial members, who would represent the interest in the settlement of the general public and also ensure a decision in case of deadlock, and provided for the enforcement of the rates fixed by the appropriate Government Department. The scope of this machinery was extended after 1918, when an Amending Act substituted for 'exceptionally low wages' the absence of adequate machinery for the effective regulation of wages as the *differentia* of the trades to which the Acts might be applied; and in 1925 it was estimated that a million and a half workpeople had their wages regulated by Trade Boards. A less revolutionary extension of Government activity was the approval given to the Whitley scheme of Joint Industrial Councils and assistance in the formation of such councils; as a result of which it was estimated, rather optimistically, that three million workpeople were covered in 1925.¹ In the same cate-

¹ Balfour Committee, *Interim Report on Industrial Relations*, p. 47.

gory may be placed the scheme of Conciliation Councils in the railway industry, embodied in Part IV of the Railways Act of 1921. Finally, temporarily by the Corn Production Act of 1917, and permanently by the Agricultural Wages Boards Act of 1924, the benefits, whatever they may be, of organised settlement of wage-rates by representative bodies were extended to the last great unorganised group, the agricultural labourers. It is not possible to compute a figure for a recent year to correspond with the 2,400,000 of 1910, because the status of collective bargaining in certain important industries is obscure; but if we add together the numbers covered by Trade Boards, Agricultural Wages Boards, Joint Industrial Councils, and Unions in certain industries, which, like coal and cotton, have adopted none of these forms of organisation, we get a total of eight millions out of a wage-earning population, which, excluding domestic service, numbers something under fourteen millions. When we remember that the influence of an agreement or a determination, reached by a representative body, tends to go beyond the limits of the membership of the organisations, and even trades, directly represented, we may safely conclude that there are few important gaps left in the provision for the settlement of wages by collective bargaining in Great Britain.

The precise nature of this change is worth some consideration. It was not the introduction for the first time of standardised rates of pay in time-work occupations. Even if we leave out of account the considerable part of the field covered by trade unionism at the beginning of the century, it is probable that in most districts, in which an occupation was followed by considerable numbers, there were customary rates commonly recognised, which the majority of employers observed. These rates were not so definite and secure as they became when they were embodied in a collective agreement; but, outside the so-called 'sweated trades,' they were a limitation on the freedom of the individual employer to vary rates. Immediately, wages were fixed for him rather than by him, although ultimately they had to conform to the demand for labour, of which he was the channel. Nor was the change an universal substitution of collective for individual bargaining about rates. In piece-work industries after the change, as before, the vast majority of rates were settled by an individual bargain between the workman and the employer's representative. The change was a change in the procedure by which general changes in wages are effected, in response to general changes in the economic conditions of a trade or of industry as a whole, and its essence was the extension of collective bargaining for this purpose from a part of the field of commercial wage-employment, say a quarter, to the whole.

The effects of collective bargaining are of course not limited to general changes in wages. It provides an opportunity of effective appeal against grievances of all kinds, which does not exist in its absence, and tends to a more definite standardisation of wages and conditions. When first introduced it usually brings about a rise in wages; the Agricultural Wages Boards, when first established in 1924, raised weekly wage-rates by an average of 3s. a week, although there was no change in the economic conditions of English agriculture to justify any such change, and the

first Trade Boards in some cases established *minima* that were double the rate of earnings ruling in important districts before. But the significant and essential change was the change in procedure. Wage-rates in any case have to be adjusted to changes in the demand for different kinds of labour, changes in the purchasing power of money, changes in the general prosperity and activity of industry. Before the war, outside the organised industries, the adjustment was made by the individual action of the employers, who first felt the need; to-day the process of general wage-changes has, we may say, been constitutionalised.

It is the system resulting from this change that I refer to as 'the public regulation of wages.' It is only partially due to the direct intervention of the State, although the legalising of trade union activity was essential to the development of effective collective bargaining without the State's direct intervention. Whether, however, wage-changes are negotiated by voluntary industrial councils, spontaneous negotiations between trade unions and employers' associations, or statutory Trade Boards and Agricultural Wages Boards, the result is the same. A change cannot be effected without public discussion between representatives; when effected, it applies generally to the trades and occupations represented; it is the outcome of an attempt to allow for all the economic factors in the situation, not of an attempt to impose *a priori* principles of social justice upon industry; it is a procedure for adjusting wages by agreement, rather than a policy aimed at over-riding the commercial considerations that have determined wages in the past. It is 'public' in the sense that it involves formal discussion by representatives, and results in publicly formulated standards; it is 'regulation,' only in the sense that it provides in this way for the formal consideration of the factors affecting wages by the representatives of employers and wage-earners, and the embodiment of the result in a formal agreement.

Although I am concerned here only with British experience, I may note that the change is not confined to Great Britain. The pioneers of this new procedure are the States of the Australasian Dominions, whose example influenced Great Britain, in spite of the difference in conditions. There the change took the form rather of the substitution of arbitral determination of wage-changes than of the extension of collective bargaining, and the results are the subject of controversy. There is, however, a good deal of evidence to support the view, that there also the change was one of procedure only. Arbitration did not, because it could not, materially affect the economic factors that ultimately determine what wages can be paid; and the course of wages, as formulated by arbitration, was much the same as it would have been—with a time-lag and less uniformity—had there been no arbitration. In other words, the arbitration authorities interpreted—and interpreted with fair accuracy—forces which they could not in any case control.²

² Cf. F. C. Benham in *London Essays in Economics* (1927), p. 226: "Our conclusion is that in the main average real wages have not been fixed much higher than they would in the absence of wage-regulation." Cf. *Report of Proceedings of the National Conference* (1928): *New Zealand*, papers by Professors Fisher and Belshaw.

II.

The extension of public regulation of wages in this sense from a part to the whole of the field of commercial wage-employment could hardly be without some effects upon the general industrial situation. In their classic study of the effects of collective bargaining Mr. and Mrs. Webb lay chief stress upon its influence in increasing the efficiency of industry. They draw a sharp distinction between the policy of restricting numbers in a trade and that of imposing common rules. Their survey of trade unionism showed that the former policy, anti-social and self-defeating, was adopted by a smaller and smaller proportion of unions, and was becoming more and more difficult of application; the discarding of any attempt to restrict numbers, and the concentration on the policy of imposing standard or minimum rates and conditions, was growing, and was the chief characteristic of trade unionism in the expanding industries. This policy increased industrial efficiency in two ways, by its reaction on the workman and by its reaction on the employer. The workman, prevented from securing employment by accepting a lower rate of pay than his competitors, was compelled to improve his efficiency, and was enabled to do so by the increase in income and security that trade unionism usually brought. More important were the reactions on the employer. Stopped from taking the easy but dangerous path to lower costs of cutting wages, he had to find other means of increasing output in relation to wage-payments. Hence trade unionism encouraged an increase in the scale of production, a more extensive use of mechanical equipment, a more eager search for technical improvements, and, generally, the economy of labour. It did not extinguish competition, but diverted it from wages to other factors in costs.

The rapid expansion of the unionised coal, cotton, and engineering industries in the decade following the publication of this analysis seemed to confirm its soundness. The decline and stagnation of the same industries in the last eight years prompts the inquiry whether this influence has exhausted its potentialities. The evidence collected by the Balfour Committee, while not decisive, points to the conclusion that labour-cost in the export industries has risen as much as, and possibly more than, wage-rates, which implies that such increase in efficiency as these industries have been able to secure has not been more than sufficient to compensate for the reduction in hours of work.³ In the trades to which Trade Boards were first applied, many instances were afforded of improvements effected under the stress of the need to economise labour, and in some of them, for instance the clothing industries, a marked increase in scale, such as the Webbs' analysis would lead one to expect, took place. We should expect the reactions of this kind to be greatest in the trades in which wages and conditions had been worst, and in the period immediately following the first application of control.

Whether the influence on efficiency has continued and is general, the abnormal condition of British industry makes it difficult to decide. The large amount of short time, the increase in other costs, and the financial

³ Balfour Committee, *Further Factors in Industrial and Commercial Efficiency*, pp. 92 *et seq.*

difficulties which prevent large numbers of firms from installing improvements, which they would like to install, all obscure the issue. Without, however, attempting to decide the larger question, we may note two things.

The first is that the contemporary experience of America shows that collective bargaining is not a necessary condition or the only means of stimulating an increase in efficiency. Since the pre-war period, while British industry with its new equipment of universal collective bargaining has at most increased output sufficiently to compensate for the reduction in normal hours, manufacturing output per head in America increased in the ratio of 105 to 147 between 1919 and 1925. In the same period the extent and strength of trade unionism in America declined, except in certain industries, in which the unions have departed from the old policy of leaving the employers to find ways and means of meeting their claims, and have assumed a direct responsibility on behalf of their members for reducing labour-costs as a condition of maintaining or increasing wage-rates.

The second note is this. In so far as the extension of collective bargaining does stimulate or compel economy in labour—and, if it has not done so on any large scale at present, it may do so in the near future—it may maintain wages at the expense of increasing unemployment. In the great export industries of coal and cotton, for example, demand for British production appears to be inelastic, and considerable reductions in cost have not resulted in any substantial increase in employment. Moreover, much of the employment at present given is given at a loss. A reorganisation that made it possible to maintain present wage-rates without loss would probably, therefore, involve a reduction in the numbers to whom employment could be given. Such an extrusion of unwanted labour, as a result of improvements in the technical processes or organisation of industry, is a normal incident of economic progress; and the hardship it may involve need be only temporary, provided that the expansion of industry as a whole is great enough and rapid enough to absorb the extruded labour. When all the industries of the country adopt collective bargaining, and all begin to adopt the policy of holding up wage-rates, leaving it to the employers to tune up industry to the pitch at which such rates can be paid, the numbers of extruded workers for whom the new and expanding industries have to find employment is likely to be increased, and the rate of expansion of industry as a whole becomes a factor of much wider and more pressing interest in wage-negotiations than before.

III.

Mr. and Mrs. Webb in their rationalisation of trade union policy distinguished sharply, as we have seen, between the effects of a policy of restriction and those of the policy of regulation. The benefits of trade union organisation to society at large, as distinct from the sectional interest of the members, accrued only if union policy eschewed restrictive practices, and, by concentrating on maintaining and advancing wages and conditions, brought about an improvement in industrial efficiency.

It is obvious that an advance in wages secured by any one class of

workpeople, if it is not covered by a corresponding increase in the efficiency of the industry in which they are engaged, must be at the expense of someone else. The increased efficiency may be due to the workpeople or to the employers; but, if neither of them create a fund from which increased wages can be paid, the increase will be paid either by consumers or by the co-operating industries that help them to supply the consumers. If the increase is merely sufficient to keep pace with an advance in the average level of wages, it may represent no more than the industry's proportionate share in the general increase of wealth; if, however, it is greater than the average, or in times of wage-reductions, the reduction is less than the average, it must involve the diversion to the favoured industry of a larger share of society's income.

Such a diversion may be effected without overt restriction of numbers. If a union—or a Trade Board or Arbitration Authority—fix wage-rates in an industry at a level which makes it impossible for the industry to employ all the workpeople seeking work, and maintain rates at that level, it will immediately restrict employment, and ultimately may so discourage entry to the industry, that the number of workpeople dependent on the industry is no greater than can be employed at the rates set. The demand for the products of industry, and therefore for labour, ebbs and flows with general fluctuations in trade; a strong union can maintain rates when demand ebbs and advance them when demand rises, thus preventing both a fall in *rates* proportionate to the general decline in money incomes in the depression, and an expansion in *numbers* proportionate to the general increase in production when trade improves. On the other hand, an unorganised industry may suffer a reduction of rates when trade declines and an expansion of numbers, on the low level of wages so established, when trade improves.

The mere regulation of wage-rates may, therefore, be restrictive in its effects. Such restriction may be legitimate and socially desirable; but it destroys any sharp distinction and opposition between a policy of restriction of numbers and a policy of imposing common rules of payment and conditions. It makes no difference, for example, to a coloured worker in countries of mixed nationality, whether he is excluded from certain occupations by a legal colour-bar, or by a legal minimum rate so high that no employer would think of paying it to a coloured worker; it makes no difference to an unemployed building labourer, whether the expansion of the building industry, to a point at which he would be absorbed, is prevented by apprenticeship regulations, making it impossible for building employers to get enough skilled men, or by the establishment of skilled rates, that raise the cost of building and restrict the demand for houses. It is not even clear that the reactions upon efficiency of the two policies are necessarily different. If the supply of a certain class of labour is restricted, employers will be stimulated to devise labour-saving appliances to substitute for it, or some reorganisation to dispense with it, just as certainly as if the supply is unrestricted but expensive. One generation of architects devised ways of using brickwork in pilasters, cornices, string courses, and around openings, because stone-masons made themselves scarce and expensive, a later generation used concrete to replace brickwork, because bricklayers had become scarce and expensive; the develop-

ment would have taken place whether the impulse came from a scarcity, or from a disproportionate rise in the cost, of the necessary skilled labour.

Trade union control of wages, and the analogous control by public wage-fixing authorities, may be most simply regarded as an application of monopoly price policy to labour. The monopoly is seldom, if ever, complete; but what monopoly is? It gives the seller of labour no control over the demand for his services; it merely enables him, so far as it is effective, to select the point on the demand curve at which he will hold the price, until a general rise in demand absorbs at that price all the union members, instead of allowing competition for employment always to force wages down to the point at which the whole supply of labour is absorbed. It is a policy that can be pursued without causing more than temporary unemployment, under two conditions; first, that the wealth of society is steadily growing, so that continually higher wage-rates can be paid without causing unemployment: secondly, that it is practised only by a minority of the trades in the community. The latter condition no longer obtains.

IV.

The industries of the country are co-operant agents in the production of the commodities and services that industry sells. So long as everybody was not organised to attempt it, it was always possible that favoured trades, by means of a monopolistic organisation, might secure for themselves a larger share of the final price received for industry's products. Marshall illustrated this possibility by a hypothetical case, which has recently been illustrated in actual experience, that of plasterers, whose services were jointly demanded with other kinds of building and building-material labour; but the possibilities are wider. Mr. Rowe has recently shown us that the true rate of advance of wages (average of skilled, semi-skilled, and unskilled grades) between 1886 and 1913 was 47 per cent. in coal-mining; as compared with 9 per cent. in the case of railways, and an average of about 25 per cent. for the five representative industries he studied. Mining is one of the instances Mr. and Mrs. Webb take, and the enormous growth of the industry in the period shows that the advances that the unions were able to secure certainly did not prevent growth. They may also have had some influence upon the efficiency of the industry; but any such increase in efficiency was not latterly sufficient to counteract the opposing influence of exhaustion of supplies; output per head in tons declined from 1907 onwards. Now the final price to the consumer of coal has to cover not only the getting of the coal, but the transport of it, and such transport is an important source of revenue to the railways. May it not be that railwaymen would have got more, and miners less, of the final price, if the railwaymen had been organised and the miners unorganised? ⁴

Just before the war the railwaymen completed an effective union organisation, which the circumstances of the war and the post-war period

⁴ South Africa appears to offer the extreme case of a distribution of the final price of coal in favour of railwaymen. The pit-head price of coal in the Northern Transvaal in 1923 was 5s. 3d. per ton, the railway rate per ton per 100 miles 7s. 4d.; miners' wages averaged £45 a year, railwaymen's £117. (Calculated from figures given in Union Year Book, No. 7.)

tended to favour; and the pull that they are able to exert upon the distribution of the price paid by the consumer for coal is certainly not less than that exerted by the miners to-day. And this change is significant of the general change in the competitive position of different wage-earning groups. All now are organised, or provided by the Government with equivalent protection; all are able to set and hold rates of wages, as firmly as the minority of well-organised trades were able to hold them before the war. Partial and sporadic monopolistic organisation has been displaced by universal control. Two consequences follow. First, it is no longer possible for well-organised trades, merely by virtue of their trade union organisation, to secure differential gains at the expense of unorganised or ill-organised groups with whom they co-operate; or, if it is still possible, at any rate it is more difficult. In the second place, influences upon wages, that were formerly counteracted by trade union organisation, have now free play. Organisation and control, having been extended generally, no longer differentiate groups, so that their influence, if not yet eliminated, is very much reduced.

From this point of view the intervention of the State, in establishing Trade Boards and Agricultural Wages Boards and in other ways, and the contemporary extension of unionism to hitherto unorganised trades takes on a rather different aspect from that which Mr. and Mrs. Webb put upon it. They represented it rather as an extension to the rest of industry of the principle of trade union control and of the benefits that they had shown to follow from trade union organisation. This, of course, it was; but it was at the same time a necessary corrective of trade union influence. So long as only a part of the field of wage-employment is covered by trade union organisation, the benefits secured by trade unionists may in part be at the expense of the workpeople in the unorganised part of the field; so far as those benefits are not the return to increased efficiency due to union pressure, they will almost certainly be in part at the expense of other wage-earners. To prevent this kind of horizontal redistribution, it is necessary to put all wage-earners on an equality in respect of organisation for wage-bargaining; it will never be possible to secure complete equality in this respect, but the changes of the last twenty years have eliminated the obvious inequality, and thereby eliminated a great part of the danger.

Trade union organisation is, however, not the only element of monopoly or other advantage differentiating different occupational groups. The extension of union organisation, therefore, or some effective substitute for it, to the support of wages throughout the whole of industry, does not suffice to put occupations upon an equality. Rather its effect is to enhance the influence upon distribution of other factors making for inequality, more particularly of those elements of bargaining-advantage, that are inherent in the nature of different industries, but were obstructed or outweighed in the past by the greater influence of unequal union organisation. The second consequence of general control is, therefore, the release of influences upon wages which were formerly prevented from exercising their full potential effect. In this release is, I think, to be found a partial explanation of the changed relations which wages in different industries bear to one another since the war. It might have

been expected, for example, that wages would be high in an industry like railway transport, which enjoyed a monopoly and had a relatively inelastic demand for labour. In fact, before the war they were low; since then the railwaymen have had the advantage of effective union organisation, and their wages have risen disproportionately to others, in spite of the invasion of the railways' monopoly by road transport and consequent depression of the industry. Another influence is 'shelter' from foreign competition, possibly only a temporary influence, but one that has operated throughout the post-war depression. Before the war, when they were organised, the 'sheltered' industries were on a level with the 'exposed' industries, compositors on a level with miners, bricklayers with fitters; to-day they are on a higher level. When they were unorganised, they were relatively poorly paid; to-day the Trade Board *minimum* for certain of them is as high as, or higher than, the standard rates of skilled men in engineering and shipbuilding. It is not suggested that the public regulation of wages is the sole or chief explanation of these divergences; the differing fortunes of the 'exposed' and 'sheltered' industries would account for even wider divergences; but regulation may explain why the 'exposed' industries have not been able to transmit to other industries a portion of their losses. Another factor that appears from a comparison of wage-movements in different occupations to be exercising a greater influence than before the war is the possibility of bringing political pressure to bear upon the employer, which the employees of public authorities can exploit. More important is the share in the advantages of monopoly, or partial restriction of competition, which employers have established and workpeople are able to share. Thus, in the textile industry the finishing trades are combined and enjoy a prosperity which the great spinning and weaving sections allege is partly at their expense; the spokesmen of the finishing trades reply that their charges have not risen out of proportion to their costs, and in particular their labour-costs, which the relatively high level of wages in these trades confirms.

We may conclude that the extension of trade union or Government control over the whole field of commercial wage-employment has cancelled an advantage, which the workpeople in the organised trades used to possess, and, by so doing, has increased the relative influence which other elements of monopoly or bargaining-advantage exercise upon wages. The extension would be an almost unqualified improvement, if its effect was to confine wage-claims to amounts that could be justified by the increased efficiency of industry, to which the control of wages contributed. Since, however, there are other conditions, which enable or encourage one trade to profit at the expense of others, and since the different controlling authorities carry on the pre-war trade union tradition of considering only the needs and possibilities of their own trade, the general extension of control may result in a general attempt to secure more wages than can be paid. This suggests a third possible result of the change that we must consider.⁵

⁵ The competition between different groups for the national income is not confined to industrial wage-earning occupations. Other classes are also affected by it. The extension of collective bargaining, therefore, may enable industrial wage-earners as a

V.

Before the war the policy of maintaining wage-rates in spite of unemployment could be practised only by the organised minority of wage-earners. The majority were unable to resist reductions that were needed to maintain employment; and any workers excluded by the policy of the stronger unions could compete for employment in industries in which wages were not held above absorption level. To-day there are no unorganised industries in this sense; wages are held up, either by trade union or Government support, generally, and workers excluded from employment by a *general* holding up of wage-rates above absorption level have no resort except unemployment relief. Before the war, again, in the absence of any general unemployment relief, it was impossible to maintain wage-rates generally at a level that restricted employment throughout industry; somewhere, usually at many points, wages (in relation to efficiency) would be reduced to the level at which expansion could take place; the condition 'in relation to efficiency' is necessary, because in fact expansion took place in the high-wage rather than the low-wage industries. Has the extension of collective bargaining destroyed this plasticity, this automatic adaptation of wage-rates to opportunities of employment?

The mere substitution of regular for informal discussion does not by itself make it more or less difficult to adjust wage-rates to varying conditions. The change is one of procedure only; it should, if it has any effect, tend to bring under notice more comprehensively and display more accurately the factors that have to be taken into account in finding the 'right' wage. If this is taken to be the wage that measures the marginal productivity of the number of workers available, it is just as likely that the right figure would emerge from the deliberations of a representative joint committee or an experienced arbitrator, as from the unco-ordinated bargainings of a multitude of isolated individuals. Moreover, as we have seen, individual bargaining is usually impracticable. The choice is rather between adjustment by discussion between representatives of organised bodies of employers and workpeople, and a guerrilla warfare waged by individual employers against the combined resistance of unorganised, but not necessarily demoralised, workers, fighting for what they conceive to be their 'rights.' The largest concessions by wage-earners to meet changed economic conditions since the war have been made by some of the most strongly unionised trades, such as iron and steel, engineering and shipbuilding. It is true that the wage-reductions

class to secure an increased share of the product of the nation's economic activity at the expense of other, still unorganised, classes. In the United Kingdom this possibility is of less importance than elsewhere, since wage-earners are so large a part of the community; though there has been some redistribution since 1914 in favour of wage-earners as a class at the expense of the *rentier* class, particularly the land-owning section of it. In other countries, where industrial wage-earners alone enjoy the advantages of trade union or Government regulation of their remuneration, backed up often by Protective tariffs, and there are large numbers in the 'unprotected' classes, particularly in agriculture, the possibility is important. With other influences the public regulation of industrial wages helps to account for the world-wide divergence of industrial and agricultural prices. Cf. an article by the present writer on *World Prices and Trade Barriers* in *The Journal of the Textile Institute*, 1928, No. 6.

in iron and steel have been made automatically under sliding scales based on selling prices ; but the willingness of the unions to adopt and adhere loyally to such a device is evidence that trade union control of wages is quite compatible with extreme plasticity of wages. It is conceivable, therefore, that the most complete plasticity might be secured by the most complete public control, since complete control would remove the fear that a reduction once conceded could never be recovered.

Again, the change in methods of settlement has not stopped the movement of wages. An examination of the Ministry of Labour's record shows that wage-changes have been more frequent, ample, and extensive than before the war. Mere movement, however, is not decisive. Greater frequency of change was to be expected, since change in general economic conditions has been more frequent, and because the practice of adjusting wage-rates automatically under sliding-scales to changes in the cost of living has spread since the war ; greater amplitude was to be expected, because economic conditions have been more unsettled ; greater extension, because collective bargaining is so much more general. It is the nature of the resulting adjustment, rather than the extent of movement, that is significant. In the post-war period we do not find that the movement of wage-rates adjusts the supplies of different kinds of labour to the demand for them. On the contrary, unemployment persists in most industries after frequent wage-adjustments. We do not even find a uniform adjustment of wage-rates to the varying economic conditions of different industries ; while, on the whole, wages are lowest (by pre-war standards) in the industries that are most depressed, there are important exceptions, relatively high wage-rates co-existing in the chief textile industries and elsewhere, with more than average unemployment. There has been a loss of responsiveness to changes in commercial conditions ; the movement of wage-rates have failed to establish an equilibrium between the supply of and demand for different kinds of labour.

If we examine the results actually brought about, the generalisation that suggests itself is that wage-rates are adjusted to the varying degrees of bargaining strength of different groups of wage-earners, in other words, to the factors whose influence was formerly obstructed by unequal trade union organisation. The commercial condition of the industry in which they are engaged is one factor in determining their strength, but not the only factor. Thus wage-rates in the 'heavy' industries reflect the depression in those industries and the inability of the unions to exact higher rates. But the textile industries, although equally depressed, maintain a level of wage-rates that is relatively high ; in cotton, wage-rates have been unchanged at about double pre-war rates since 1922, partly because the difficulties of the industry are so great that the operatives feel that any sacrifice on their part would be unavailing, partly because the financial difficulties of a large section of the employers have made it impossible for them to face a strike. Similarly the railway directors may think that it would pay the companies and the country to reduce their charges to the depressed heavy industries, but they cannot make further concessions, unless they can reduce their own expenses, in which wages are the most important and the most expanded, and, their demand for the labour they retain being inelastic, they cannot force a

reduction there. And so with other competitive inequalities. In the industries sheltered from foreign competition, the workers have been able to exploit the 'shelter.' Where subsidies have been paid the unions have secured for their members a share of the subsidy. Where an industry or section of an industry enjoys some element of monopoly, wage-rates, when compared with wage-rates in the other sections of the industry, suggest that the monopoly profits are shared by labour. In industry in general, the lower-paid classes of workers, who secured greater proportional advances during the war, have so far been able to retain their advantages, a power explained by the spread of trade unionism among them and Government protection of wage-rates through Trade Boards.

Thus the movement of wage-rates does not bring about an adjustment to the capacity of the different industries to pay wages and provide employment to the workers seeking employment; the set of wage-rates it results in represents the power and opportunities, often temporary and accidental, that organised workers have had of exacting wages, with little or no regard to the ultimate demand for labour as shown by the extent of unemployment.

In producing this result the extension of public and collective regulation of wages has been an influence. By preventing the nibbling at them by hard-pressed or unscrupulous employers, that undermines standards in unorganised trades, it tends to adjust rates to the capacity of the larger and better-organised firms. More important, it opens the door to the influence of non-economic factors. The mere fact of publicity, or organised discussion, invites appeal to social and ethical standards of 'fair' and 'living' wages, to pseudo-principles such as the sanctity of pre-war *real* wages, to the unpopularity of reducing rates of wages of the lower-paid workers, none of which have any bearing on the capacity of industry to pay wages and provide employment. Economists in the seclusion of a private circular may state baldly that 'the fundamental hindrance to recovery . . . lies in the abnormal relationship between the movement of the cost of materials and that of the cost of labour,'⁶ but directors of large companies, who may be candidates for Parliament, will not commit themselves publicly to such unpopular opinions.

VI.

The increased element of publicity and public control of wages, therefore, will tend to harden wage-rates in a depression, provided that the representatives of the wage-earners really wish to resist reductions. Whether they will do so or not, however, will depend on the consequences of successful resistance, at which we must glance. Before the war the consequence would have been unemployment; and unemployment would have involved, for the small minority of wage-earners covered by trade union unemployment insurance a drain on the union funds; for the great mass of wage-earners, who had no such resource, early and extreme hardship. It was impossible for the representatives of the wage-earners in wage-negotiations to ignore unemployment.

⁶ London and Cambridge Economic Service : Bulletin of October, 1928, p. 3.

To-day things are different. Successful resistance to a reduction may still involve unemployment, but unemployment does not involve the same certainty or degree of distress. Before the war the provision for unemployment relief was partial and inadequate. To-day there is a system of unemployment relief that covers all the industries that are liable to serious unemployment. Then the spokesmen of the wage-earners had to consider the employment situation, because their clients would be the chief sufferers, if their wage-policy restricted employment; now, in such a case, they may nevertheless persist in their policy, since they are conscious that their clients are not without resources, if all cannot be employed at the level of wages exacted.

It is not that unemployment relief leads to the refusal of available work; the Employment Exchanges provide an adequate check on that abuse, were there any general inclination towards it. Nor does the relief, as it is administered, impose any insuperable check upon mobility between district and district or trade and trade. The Courts of Referees and the Umpire, who decide on doubtful claims to benefit and administer the provision in the Acts that the applicant shall be 'genuinely seeking work' but unable to obtain 'suitable employment,' while they treat each case on its merits, have in general put an interpretation upon these terms, that requires the unemployed workman sooner or later to accept work outside his own district or trade, if it is available.

The effect of unemployment relief is indirect. It influences wage-rates by disinclining the representatives of the wage-earners to take the same account of unemployment as they did before relief was provided. Two incidents of the scheme strengthen this tendency. In the first place the unemployed are not an undisturbed mass of permanently unemployed workpeople, but a body the composition and membership of which is constantly changing. Hence a ten per cent. restriction of employment in an industry does not involve the relegation to continuous idleness of 10 per cent. of the workers in the industry, but irregular employment for perhaps 30 or 40 per cent.; the evil of unemployment is diffused, and there is a chance that intermittent employment at the higher rate will bring in as much as regular employment at a lower rate. In the second place the system of organised short-time makes it possible to dove-tail periods of wage-earning with periods of unemployment relief. Right to benefit under the unemployment insurance scheme does not begin the moment a worker falls out of employment, but only when a waiting period of a week has elapsed; any three days of unemployment, however, within six consecutive days or two unemployment periods of at least three days each separated by a spell of not more than ten weeks' work, are treated as continuous unemployment, and a second 'waiting period' is not required. Employers have adapted their engagement of labour to these conditions, and thus spread the available employment over a larger number of workers than the industry could employ full-time, at the same time throwing on the unemployment insurance fund the burden of maintaining the surplus labour when it is not in employment. Instituted as a device for tiding over a temporary depression, this system has been prolonged as year succeeded year of unemployment, and has had the effect of substituting intermittent and irregular

employment for regular work in industries in which such conditions were formerly rare.

This comparative disregard of unemployment in wage determinations is as distinctive a change from pre-war practice as the extension of collective bargaining, and much more significant for the problem we are now examining. Summing up the practice of trade unions at the beginning of the century, Mr. and Mrs. Webb pointed out that the unions had 'a rough and ready barometer to guide (them) in this difficult navigation.' They continued :

'So long as a trade union, without in any way restricting the numbers entering its occupation, finds that its members are fully employed, it can scarcely be wrong in maintaining its Common Rules at their existing level, and even, after a reasonable interval, in attempting gradually to raise them. . . .

'When the percentage of workmen out of employment begins to rise, it is a sign that the demand for their particular commodity has begun to slacken . . . although it can in no way be inferred that the slackening of demand has been caused by the rise in the level of the Common Rule, rather than to any other of the many possible causes, yet this slackening, however it is caused, must necessarily check any further advance. For assuming the workmen to rely exclusively on the Device of the Common Rule, it will not pay them to obtain a rise . . . at the cost of diminishing their own continuity of employment. To put it concretely, whenever the percentage of the unemployed in a particular industry begins to rise from the 3 or 5 per cent. characteristic of "good trade," to the 10, 15, or even 25 per cent. experienced in "bad trade," there must be a pause in the operatives' advance movement.' ⁷

If organised workpeople in this way took unemployment as an index of industry's capacity, and adjusted their claims accordingly, unorganised workpeople certainly could not do otherwise. Any temporary success that the latter might achieve in maintaining or advancing wage-rates, where commercial conditions called for a reduction, would have the effect of excluding from employment a mass of labour that would press upon the restricted openings for employment, and inevitably, in the absence of trade union or trade board support, lead to individual concessions and the disintegration of wage-standards.

Hence pre-war industry exhibited a fairly close correlation between the movement of wage-rates and employment as measured by the (inverted) trade union unemployment percentage curve. There was a lag, but, allowing for this, a fairly close adjustment of wage-rates to changing commercial conditions. This correlation is not to be observed in post-war industry since 1922. In the great upward movement of prices from 1914 to 1920 and in the ensuing collapse from 1920 to 1922, wages followed other prices ; but since then wages on the average have changed very little, while both prices and unemployment have varied considerably. If we consider, not the average movement, but the independent and divergent changes in wage-rates in separate industries, what we notice is not an adjustment of wages to conditions of employment, but, as is

⁷ *Industrial Democracy* (1902), pp. 738 et seq.

pointed out above, an adjustment to the varying capacity of different groups of workpeople to resist reductions or exact advances.

This post-war disregard of unemployment in wage negotiations is the principal and direct explanation of the loss of plasticity in wage-rates. It should be noted, however, that the provision of unemployment relief is not the only cause of the change. We have already come across another reason for it in connection with the cotton industry. The representatives of the wage-earners, quite rightly in many cases, believe that any concession on their part would be unavailing. The post-war depression in many industries is so much deeper and more widespread that any practicable reduction in wage-rates would hardly affect it. The example of the coal industry, in which a substantial reduction in wage-rates has been followed by increase in unemployment—and in losses by the employing firms—is pointed to as evidence of the futility of wage-reductions; and no attempt is made to gauge the extent to which demand is as inelastic for the products of other industries as it has proved to be for coal.

There is an explanation for the wage-earner's attitude in yet another change; wage-rates of direct labour never were the sole determinant of costs, and to-day they are probably less important than before the war. Loan charges, incurred in the boom and subsequent slump, although in process of liquidation, are still proportionately much heavier than before the war; rates and taxes and social insurance contributions are much heavier; indirect costs, which may be due to the level of wages, but not of wages in the industry concerned, for transport, financial services, etc., are higher; distributing costs have increased disproportionately. Hence the wage-earner, asked for concessions, fears that he is being asked to make a sacrifice, not to revive trade, but to lessen the losses, or increase the profits, of retailers, banks, loanholders, railways, and co-operating industries, that may be more prosperous than his own. The consideration of wages is purely sectional, industry by industry and trade by trade; the need of industry, so far as wage-adjustments can meet it, is for an all-round reduction, which will affect the indirect costs, simultaneously with the direct costs, of every industry. No machinery exists for such co-ordinated and synchronised adjustment; on the contrary, the extension of collective bargaining has probably intensified and extended the influence of this sectional outlook of industry by enabling industries, that before the war could not have resisted the pressures imposed by general trade depression, to hold up wages.

The general relations of wage-rates to other prices and to employment are also significant of maladjustment. Professor Bowley's new index number of wages shows an advance (at the end of 1928) of 94 per cent. over the pre-war level, while the cost of living, as measured by the Ministry of Labour's index, has risen only 67 per cent., wholesale prices, as measured by the Board of Trade index, only 38 per cent. and the average price of British exports only 61·8 per cent. Wage-rates on the whole have been remarkably stable since 1922, although unemployment, as measured by the registrations under the unemployment insurance scheme, has fluctuated from over 17 per cent. in 1922 to less than 10 per cent. in 1924, rising again to over 12 per cent. in 1925 (to 14·6 per cent.

during the coal stoppage), falling to less than 9 per cent. in 1927, and rising again to over 12 per cent. in 1928. The chief instance of this maladjustment of wages is perhaps to be seen in the maintenance of the average level of wage-rates (in spite of a large reduction in the important item of miners' wages) since 1924, while other prices were being adjusted to the level required by the return to the Gold Standard. Money wages have been maintained (which means that real wages have increased about 8 per cent.), while the prices which British industry received for its products, as measured by export prices, were reduced on an average $14\frac{1}{2}$ per cent., and the number of unemployed, comparing 1929 with 1924, increased. Comparisons of wage-movements with physical volume of output point to the same maladjustment. Real wages increased on an average by 12 per cent. between 1907 and 1924; a comparison of the Censuses of Production of 1907 and 1924 suggests that output per head did not increase, or increased only very slightly.⁸

It would appear, therefore, that wage-fixing authorities, acting independently of one another and disregarding the general economic situation, are maintaining wage-rates at a level at which existing industries cannot provide full employment; the considerations that explain their policy will not serve to explain away the unemployment that has accompanied it. The outlet for labour thus excluded, which was provided before the war by industries in which wages were not controlled, no longer exists. There remains for examination the possibility that new industries may provide an outlet, industry as a whole expanding sufficiently to absorb the excluded labour.

VII.

Before the war we had no measure of industrial expansion; but there was no evidence of cumulative unemployment, so that industry must have expanded at much the same rate as the growth of population. Since 1923 we have had, in the unemployment insurance statistics, a record of the directions in which industry is expanding and contracting, which, with certain other information, supplies such a measure. It would seem that industry has, temporarily at any rate, lost its capacity of expansion. In insured industry, which covers about three-quarters of wage-earning employment, the expansion of employment has been barely sufficient to absorb the diminished increase in the population seeking employment, without affording any relief to the mass of unemployment afflicting industry.

In certain directions there is expansion, but a closer examination compels us to discount any hopes derived from it. The largest single increase in employment has been offered by retail distribution, 360,000 or 31 per cent. between 1923 and 1928. A part of this may be at the expense of the small shop-keeper, who does not come into the insurance figures, in which case it, however, represents no net increase of employment; the greater part probably does represent a net increase, but an uneconomic increase. The Balfour Committee brought together material

⁸ A. L. Bowley, *A New Index Number of Wages*, pp. 4-5.

that suggests that retail distributing costs rose in greater proportion than prices generally between 1914 and 1925 ;⁹ since then we have had a further great increase in the number of insured persons employed in retail distribution. This expansion of the retail margin, coupled with the enormous expansion of newspaper advertisement revenue in the same period and the elaboration of competitive selling organisation, has been sufficient to neutralise and make of no effect in the final price to the domestic consumer of British goods much of the writing down of capital, reduction of wages, and economies of re-organisation by which productive costs have been reduced. By keeping up the cost of living, while wholesale prices are falling, these costs also make it difficult to ask for any reduction in wages. So far then as retail distribution provides additional employment by its expansion, it probably does not succeed in compensating for reduction in industrial employment, which the cost it imposes on industry involves.

The second group of expanding industries is the building, building material, and furnishing industries. Together these account for 211,000 increase in the five years. Here the explanation is partly the demand due to interruption of building during the war, partly the large subsidies given to encourage building. The war-time arrears have now been made up, so that further expansion will be limited to the needs of the increase in population and of replacement with the aid of further subsidies. The case of the third group is similar. These are industries in which expansion has been stimulated by protection, but would have taken place without that stimulus, under the more economic stimulus of technical invention ; motor manufacture and artificial silk are the chief members of the group. It is difficult to estimate how much of the growth was dependent on protection and merely a diversion from unprotected industries ; but the aggregate expansion of the two together would not be sufficient to compensate for half the contraction in coal alone. So far from the expanding industries showing any likelihood of replacing permanently the loss in employment offered by the older, contracting industries, it would appear that they cannot be relied on even to provide continued employment for their present complement of workers. The new situation requires, if it is not to exaggerate the difficulty of the post-war unemployment problem, a more rapid growth of new industries, of expansion in new directions than before the war ; actually, the rate of expansion and capacity for growth appears to have seriously diminished.

VIII.

My object in this review of wages and employment has been to discover the consequences of the change in methods of settling wages that I described at the outset. I have been led rather wide of my subject by the difficulty of distinguishing these consequences from those of other contemporary changes that have interacted with it. It remains in conclusion to point out that the loss of plasticity, and the adverse effects

⁹ 'The amount of expenses per £ of sales (in certain representative establishments) was on an average probably 35 per cent. greater than in 1913.' *Further Factors*, p. 117.

upon employment that may follow, are not necessary and inevitable consequences of the extension of collective settlements, but, in so far as they are attributable to it, due rather to an obvious defect in the machinery and current practice of collective bargaining than to anything inherent in collective bargaining as such.

The changes that distinguish the post-war wage situation, public control of wage-settlements and public relief for unemployment, are instances of the operation of the habit, described by Dr. Cannan as 'proposing remedies for economic pressure without considering the question whether that pressure may not be an integral part of the existing organisation which cannot be removed without causing disaster unless some efficient substitute is provided.' We have interfered with the harsh but effective correctives of wage-demands that restrict employment, namely, the loss of income by unemployment and the expansion of employment where wages are not held up. Either, therefore, we must devise alternative correctives, or we must expect unemployment on a large scale from this cause alone.

It is not likely that any party in industry or politics will propose to restore the old correctives. The suffering caused by unemployment before the war, a repetition of which on a greater scale the extension of the unemployment insurance scheme has prevented, was too hard a price to pay even for a nice adjustment, which it did not always secure, of wages to the demand for labour. Still less likely is it that the extension of collective bargaining will be reversed. Its completion was needed, as we saw, to prevent the unconscious exploitation of ill-organised and unorganised groups of wage-earners by the well-organised minority; and the removal of this inequality points rather to the need of attacking other inequalities and elements of monopoly that obstruct an economic distribution of the product of industry.

The defect in the machinery for wage-negotiation to which the present unemployment points is the purely sectional character of its deliberations. It is no one's business to consider wages as a whole, there is no authority charged with the duty of reminding wages boards of their responsibility to industry in general. Collective bargaining must fail in securing an accurate adjustment of wages to industrial conditions, so long as it is confined to negotiations over wages in individual trades and industries. If it is to continue, it must be supplemented by some device for ensuring that the negotiators in each trade and industry have regard to the effect of their determinations upon other trades and industries, and for compelling them to contemplate the needs of industry as a whole. The 'barometer,' by which, according to Mr. and Mrs. Webb, the organised industries were guided before the war, the extent of unemployment in their own industries, is no longer trusted; but, even if it were, it would be inadequate and misleading, since a trade union might pursue a policy that caused unemployment in other trades without causing unemployment in its own.

Moreover, by considering only its own needs and interests, an industry might pursue a policy that was restrictive in effect, though regulative in form. If all industries and all trades pursue such a policy—and all now have the requisite organisation—and maintain rates of wages that restrict

employment, there will be excluded a mass of workers who must either be absorbed by new industries, or remain unemployed. If there are new industries capable of absorbing them, well and good ; but at the present time it would seem that there are not. The index or barometer, therefore, to which trade union and arbitration authorities' attention should be directed, is not solely, or even principally, unemployment in the industry immediately under consideration, but the rate of expansion of industry as a whole.

A wage-rate is a price, and every price is a function of every other price in the same field of demand and the same area of supply. The fixing of a wage-rate may, therefore, affect the demand-price and supply-price of every other kind of labour working for the same market. The organic nature of the system of wage-rates was abundantly illustrated during the war, when public intervention at one point led to reactions that compelled intervention at other points, and finally to the attempt to control all wages. It has received a more painful illustration since the war in the persistent unemployment and check to expansion that have accompanied the purely sectional handling of wage-problems. The task of co-ordinating wage-settlements in different industries, and of securing in each the consideration of such apparently remote factors as the productivity and rate of expansion of industry as a whole, may be too much for the spontaneous democratic machinery by which collective settlements are negotiated at present ; but the alternative is almost certainly a breakdown of that machinery under the pressure of a growing problem of unemployment.

SECTION G.—ENGINEERING.

SCIENCE AND ENGINEERING.

ADDRESS BY

PROFESSOR F. C. LEA, D.Sc.,

PRESIDENT OF THE SECTION.

It is not unusual for a President of this Section of the British Association to choose for his Address some particular branch of engineering with which he has been actively engaged. During the last twenty-five years I have been closely associated with Universities in which the training of young engineers forms one essential part and research a second, although by no means secondary, part of their activity, and it seemed fitting to deal in this address with one or other aspect of that experience. So much has been said and written upon the subject of the type of training that is best for engineers and there are so many diverse opinions of the most suitable course to be adopted for the training of this and that type of engineer that it appeared presumptuous for me to use this opportunity to advance any particular views that I might hold. It seemed in every way better to give attention to the second aspect of university work, to emphasise the importance of the scientific method and research in engineering and in engineering training, illustrating my remarks by reference to several branches of engineering and particularly those with which I have been most closely associated. Further, it seems desirable that the address of a President of a Section shall assist in the primary objects for which the Association exists. Sir William Bragg, in his Presidential Address at Leeds last year, pointed out that one of the purposes of the founders of the Association was 'to obtain a more general attention for the objects of science,' and the first general secretary of the Association nearly one hundred years ago wrote 'the primary purpose of its annual meetings should be the stimulation of interest in science at the various places of meeting and through it the provision of funds for carrying on research.' A number of early Presidents of the Association emphasised the place of science in the intellectual life of the people and the beneficent influence of the Association in securing a more general attention to the objects of science, and one of them pointed out the importance to the community of a body of scientific workers 'free alike from the embarrassments of poverty or the temptations of wealth.' In pressing these claims for public interest in science they had not in mind the applications of Science to the material ends which the engineer has in view, and sometimes surprise has been expressed that an Engineering Section should find a place in the meetings of the Association; nevertheless it seems desirable to suggest that, as engineering is so closely related to very many of the activities of modern life and uses for its purposes the discoveries of nearly every branch of science, the aims of the Association are of particular importance in relationship to this section.

The economic and beneficent importance of the work of the engineer is recognised by all, in the provision of safe, reliable, and efficient means of transport and in the wonderful harbours and docks which make possible the interchange of commodities between the nations and incidentally the sharing of your gracious hospitality by so many of us from Great Britain; in the utilisation of sources of energy for doing the work of the world; in the equipment of factories and workshops with machines that produce abundantly so that the standard of life is raised; in supplying to communities pure water, and in the disposal of sewage without danger to health or to the contamination of rivers and streams; in making it possible to plough the great spaces and gather the abundant harvests with little labour; in the provision of implements to combat the enemies of the fruit harvest, and in the construction of dams and reservoirs to store the abundant rains for the time of drought so that even the barren places shall be fruitful and rejoice. For these achievements of engineering it is not difficult to obtain recognition, but it is often overlooked that engineering is affecting the intellectual outlook of peoples and by its very successes may introduce social and political problems of great significance. The development of the steam engine and the invention of certain types of machines during the eighteenth century changed the industrial life of England and to-day there are social and political problems, particularly those incident to distribution and concentration of population, that are left as a legacy of the rapid changes in manufacturing conditions and a failure to appreciate at the time the new influences that were moulding the life of the nation. During the last century the work of the engineer has surely had a very marked influence upon the relationships between the nations. Great liners now traverse the broad highways of the seas and iron roads cross continents so that distant peoples are brought near together and the relationships between the nations are irrevocably changing for good or ill. The control of power and mechanical skill have made it possible for the spoken and printed word to disseminate widely thoughts and opinions, so that the worthy and the unworthy have opportunities of influence hitherto impossible. If, therefore, it cannot be claimed that engineering has a direct influence on the intellectual life of peoples and their political relationships it has an indirect influence, the full significance of which it is at present difficult to evaluate. A clearer recognition, however, of the factors and influences that modern engineering is bringing into the life of the world, and particularly their potentialities for good or ill, as well as their effect upon the incidence of populations and the social and political problems of the future, should not be overlooked, and the hope can be expressed that directly and indirectly the contributions of engineering may be used for beneficent and not destructive ends. Communities, not engineers, are responsible for the use or abuse of the gifts of engineering.

It is not, however, desired in this address to emphasise the intellectual or political influences of engineering but rather to suggest: (1) the vital importance of scientific research to engineering, (2) that as in the remarkable engineering developments of the last century the scientific method has been the key to progress even so it must be in the future, and (3) that there are many engineering problems of great interest and importance, not only

to engineers but to the general public which can only be solved by supplementing experience by direct and indirect attack, using all the aids that mathematical and experimental science can give. It is also desired to suggest that all the arguments for a public interest in scientific research apply with particular force to the work of this section.

It has been said and with truth that engineering is much older than modern science. In Mesopotamia and in Egypt, long before the dawn of the Christian era, irrigation and other works of great magnitude were carried out. Two thousand years ago the Romans made roads, constructed waterworks and erected bridges that fill us with admiration and wonder. The engineer to-day has to guide him the accumulated experience of many thousands of years and for a solution to many problems with which he is faced he has to fall back upon this accumulated experience and to his intuitive ability. For this reason it is sometimes argued that engineering is an art and that it owes little to science. Recently an important engineering journal wrote, 'The idea that engineering is based upon scientific knowledge is both wrongful and harmful, as it is generally understood. We had bridges before there was a theory of continuous girders and steam engines before there was any theory of thermodynamics.' That engineering is an art demanding that creative ability and doing associated with art, as distinct from knowing in the strict scientific sense, is true and it is also true that there were bridges and prime movers before there was any organised theory of structures or thermodynamics, but it does not appear true to say that there was any possibility of such bridges as the Forth Bridge, the Sydney Harbour Bridge, the Zambesi Bridge, and the Hudson River Bridge of 3,500 feet span, now in process of construction, before the birth of modern science and the scientific method. Neither was there a useful steam engine or other great and efficient prime mover before there came into the intellectual life of Europe that wonderful renaissance out of which modern experimental science was born. The Eastern scholars who came to the West after the fall of Constantinople brought amongst their treasures the works of Ptolemaic philosophers, in which were described experiments with heated air and steam, the reciprocating pump, simple water-wheels and many ingenious mechanical devices. For 1500 years Roman and Mediæval Europe had neglected experiment and from Hero to Galileo little or no progress was made in the development of structures, machines, and prime movers. The revival of the experimental method leading to the wonderful conquests of physics and chemistry and in the new attempts to co-ordinate the results of experience into a body of theory, assisted by the new mathematics, gave to engineering that impetus and assistance necessary for the achievement of the last century.

'Meanwhile let no man look for much progress in the sciences, especially in the practical part of them—unless natural philosophy be carried on and applied to particular sciences and particular sciences be carried back to natural philosophy' wrote Francis Bacon in 1620 (Aphorism LXXX, *Novum Organum*). Twenty-four years after Bacon wrote these words Galileo died and in the same year Sir Isaac Newton was born. From their joint labours, carried out without any desire of practical usefulness, came the principles of mechanics without which, it is surely not too much

to say, much of the progress of the last three centuries would have been impossible. Before Savery and Newcomen produced the first successful steam engine many experiments on the pressure of the atmosphere, the relation between pressure and volume in gases and the production and the condensation of steam had been made by Porta, de Caus, Torricelli, Papin, Boyle and others; a group of students had gathered together in London, 'inquisitive into natural philosophy,' and from these gatherings arose the Royal Society; also Galvani had discovered voltaic electricity with all its potentialities for engineering and the world. Seventy years after Savery's first engine was constructed, the greatest step in the development of the steam engine was made by James Watt, not surely as an invention in the ordinary sense, but as a splendid deduction from the quantitative knowledge of the latent heat of steam obtained from the epoch-making experiments of Black and Watt, and the earlier work of Torricelli, Boyle and others on the pressure of the atmosphere; without these prior experiments it seems very doubtful indeed whether Watt's great invention of the independent condenser and the air pump would have been possible.

'The invention all admired and each how he
To be the inventor missed; so easy it seemed
Once found, which yet unfound, most would have thought
Impossible.'

But though all may have admired, it was by rather a painful process that Watt was able to gather the fruits of his achievement. The experience of the pioneer engineer has not infrequently been that of the servants of an Eastern Caliph, who repressed too great popularity amongst his generals by ordering 'if the enterprise succeed let the booty be equally divided among my whole army: if its success be doubtful let him lose his head.'

A little more than sixty years after Watt built his first steam engine, Michael Faraday, supplementing by his unique genius the experimental work of many who preceded him, discovered that a magnet could be made to spin round a fixed wire through which a current of electricity was flowing and a wire containing a current could be made to spin round a fixed magnet. Without these and other equally fundamental experiments the wonderful developments of the generation and transmission of power which have taken place during the last fifty years, as well as the application of electricity to almost every need of the engineer, would have been impossible.

It is true that Carnot and Clausius came after Watt to perfect thermodynamic theory, and the modern theories of electricity were not known when Siemens made his first dynamos, but experimental and mathematical science had shown the way to engineering developments of the greatest significance to the life of the world. It has already been noticed that water-wheels were known and used to raise water 2,000 and more years ago, but in the seventeenth century water-wheels were little different from those described by Vitruvius in the first century before Christ and had efficiencies well below 50 per cent. In the latter part of the eighteenth century and the beginning of the nineteenth, organised experiments on

the flow of fluids had been carried out, relative velocities, momentum and kinetic energy were well understood and the next step was made by Poncelet in 1832, who enunciated the guiding principles underlying the design of vanes receiving moving fluids, and from that time progress has been so remarkable that to-day water turbines of more than 70,000 h.p. having efficiencies greater than 80 per cent. are being constructed and millions of horse power are being generated by water-power. The brilliant achievements in the development of the steam turbine of Sir Charles Parsons and others following in his steps are to-day well known. At the beginning of the nineteenth century there were probably 10,000 engines in England giving a total horse-power of about 200,000. To-day steam turbines each capable of developing more than 200,000 h.p. have been or are being made for stations in various parts of the world. It seems very doubtful if this could have been possible except as a consequence of the work of Poncelet and two centuries of scientific experiment. It is fifty years ago this year since the first food-carrying ship was fitted with refrigerating plant; if experiment and thermodynamic theory had not shown the way a commencement would hardly have been conceivable, and the developments of refrigeration, which are of such importance in the food supplies of to-day, would hardly have been possible. To many other examples of the direct indebtedness of engineering to science reference might be made. The rapid developments of high-tension distribution of power have been made possible by research in the laboratory. Many attempts had been made to utilise the explosive force of gunpowder, hydrogen, and coal gas for power production before the modern four-cycle internal combustion engine was developed, but without success, until it was recognised from thermodynamical considerations that compression is essential before ignition. The principles of geometrical and dynamical similarity based upon strict mathematical reasoning have been of the greatest service in the development of ships, aeroplanes, and airships. In 1862 a committee of the British Association reported that models could not be used to determine the resistance of ships. William Froude, however, disagreed with the committee and enunciated his well-known principles of similarity and showed how the wave-making and frictional resistances could be separated from each other and the total resistance of the ship obtained from experiments on models. Osborne Reynolds and Raleigh extended the argument to fluids having different densities and coefficients of viscosity, and it is thus possible from experiments in one medium to anticipate the resistance and forces acting upon similar models in other fluids. By using Clerk Maxwell's elegant principles of reciprocal displacements the forces and moments acting in statically indeterminate structures can be determined experimentally from models, which cannot be obtained, or only with great difficulty, by mathematical analysis. Sir David Brewster, one of the founders of the British Association, discovered more than a century ago that transparent substances when subjected to stress require double refractive properties. Taking advantage of this property, Professor Coker, using the precise aids of optics and mathematics, has from models been able to throw much light upon the nature and magnitude of the stresses in structures and machine elements. The work of Sorby on the

micro sections of rocks has led to microphotography of metals, which has been of the greatest assistance to the metallurgist in the development and control of those metals which have played such a revolutionary part in modern engineering. Unfortunately, sufficient use is not made by engineers of this powerful aid to uniformity of product. In the workshops to-day optical methods are used to make true surfaces, and unskilled men use the electric arc and the diffraction grating spectroscope to check rapidly the analyses of bars of various alloys, confusion in which may lead to disastrous results in engines and machines. Accurate pyrometry and uniform distributions of temperature in heating furnaces are essentials of success in many branches of engineering using alloys of steel and aluminium, cold-worked metals and many other forms of materials. Loss and failure are the serious penalties paid for inaccuracy or inability to use these aids. The judgment of the craftsman and the old 'rule of thumb' methods, which sufficed until comparatively modern times and which, unfortunately, are sometimes practised to-day, are unreliable and lead to serious lack of uniformity in production and not infrequently to failure where success could have been possible.

Thus it can be said that the important steps that have been made in engineering during the last hundred years and that distinguish this century from all preceding ones were commenced and made possible by fundamental discoveries of science, and it can safely be anticipated that no new epoch-making developments in the future will be possible unless preceded by new fundamental scientific discoveries. Sufficient energy can be transmitted across oceans by directed beams to allow of telephonic communication. It seems improbable that wireless transmission will be possible for the large outputs of power-generating stations, but what the future is to reveal cannot be known. In any case the fundamental scientific work of Maxwell, Crookes, Hertz, and Fleming was essential before even a start could be made.

At present we depend upon the natural forces of air and water or the energy of controllable chemical reactions in boilers, engines, and batteries for our sources of power. Visions of engineers controlling sources of atomic energy immeasurably more powerful than those available at present sometimes come to the hopeful, inspired by the developments of experimental and mathematical physics. Rutherford has shattered the nucleus of the atom. Dr. Krapitza, in the Cavendish Laboratory at Cambridge, has claimed to have reached temperatures of $1,000,000^{\circ}\text{C}.$, and Eddington tells us that in the great power houses of the sun and the stars, where the temperatures are, it is estimated, as high as $40,000,000^{\circ}\text{C}.$, the energy of the escaping electrons of the atoms is the source which for millions of years has made and will make it possible for the sun and stars to radiate energy without appreciable fall in temperature.

It may be, and until man is more worthy at least it is hoped that it will be, impossible for atomic energy in large quantities to be obtained and controlled. Also it may be equally impossible to obtain energy by the synthetic building up of other elements from the fundamental element hydrogen, which can be obtained in abundance by the electrolysis of seawater, but whatever the future has to unfold it seems certain that only by following the new ways opened by pure science can there be hope of

success. Perhaps it may be that not along this path that modern physics seems to suggest will the new knowledge come but, as many years ago there came the new and wonderful discovery of voltaic electricity while Galvani was making experiments with frogs, so in the future a biologist or chemist or physicist, working on some subject entirely remote from the production of energy, may make discoveries which the Watts and Faradays of the future may use to change the life of the world.

From the point of view, then, of developments in engineering, modern communities cannot afford to neglect the encouragement of scientific research even in those subjects which at present may seem most remote from its activities. Upon almost every section of this association engineering lays tribute and in return engineering has given something at least to make possible much of the brilliant work associated with other sections. The precision of modern engineering made possible the manufacture and control of the great telescopes and other instruments upon the accuracy of which the possibility of testing the attraction, predicted by Einstein, of the light rays of the stars by the sun depends. The latest apparatus by which Michelson repeated the classical experiment associated with his name and that of Morley is a triumph of engineering skill; geology owes much to the data supplied by borings and underground workings, and the work of many other sections has been facilitated by the work of the engineer.

Having, however, recognised the debt of engineering to science for the discovery of new principles and new facts which have been used as the starting point for new developments, and the dependence of engineering upon pure science for any new and important future developments only part of the story has been told. In his essay on James Watt, Francis Arago wrote in 1834: 'There are two things to be considered in every machine; on the one hand the moving power and on the other the arrangement, more or less complicated, of the moving parts,' and he might have added—the difficulty of materials suited to the new purpose. He further says that 'those persons devoted to speculative exertions are little aware of the distance there is between the project . . . and its realisation . . . the enterprise increases in difficulty and in uncertainty in proportion as it requires the efforts of more artists and the employment of more material elements.'

In the workshops, in design, in choosing materials, very considerable difficulties have to be overcome before success is possible. The principles of the independent condenser were clearly grasped by Watt, he tells us, as he walked over Glasgow Green, but many years of labour experimenting with materials, many ingenious mechanisms were necessary before the steam engine was at all perfect, and in every step that has been taken in the direction of higher pressures and higher temperatures, new materials, new processes, and new ingenious devices have been necessary before success could be achieved. Inventive ability allied with experiments, research in the development of new metals for tools and machine elements, precise measurement, the perfection of machine shop methods, especially the very extraordinary improvements in machine tools encouraged by the new tool steels and electric driving and control, have all contributed, and wherever success has been sure the methods of science have been followed.

But though so much has been done in the development of prime movers there is perhaps no movement in engineering to-day that is of greater interest, not only to engineers but to the general community, than the attempts that are being made to considerably increase the efficiency of power production from coal and other fuels. The average overall thermodynamic efficiency of the public stations distributing electrical energy in Great Britain for the year ending March 1928 was about 15 per cent. The best station had an efficiency of 21·3 per cent. Recently a power unit has been supplied from England to Chicago which on test gave an efficiency of 34 per cent.—a remarkable figure. Making allowance for boiler losses, efficiencies of from 25 to 35 per cent. ought to be possible, therefore, in the future and if only suitable materials can be developed to meet the onerous conditions of temperature, corrosion and erosion, higher efficiencies than 35 per cent. may be anticipated with steam plant. Still higher thermodynamic efficiencies may be expected, as well as the chemical riches of the coals preserved, if, as a result of research, solid fuel engines or gas turbines can be developed. At the temperature of from 400° F. (205° C.) to 600° F. (315° C.) at which boilers and superheaters have until recently worked, mild steels have been found suitable. To realise higher efficiencies than at present, much higher temperatures will be required, and at contemplated temperatures of 1000° F. (538° C.) and upwards carbon steels creep at low stresses. Below a certain stress, at a particular temperature, which I have ventured to call 'The Limiting Creep Stress,' the creep ceases or becomes so small that it cannot be observed in, say, a number of days. This 'Limiting Creep Stress' is evidently the important factor in the problem of high working temperatures. Experiments indicate that with alloy steels limiting creep stresses much higher than those obtained from carbon steels may be expected and that alloys of iron, nickel, chromium and with or without other alloyed elements, containing as much as 60 per cent. of nickel and chromium have considerable strength at high temperatures and also resist corrosion and erosion. There is still, however, a very large amount of research to be done in which the laboratory and the workshop must co-operate, as new workshop technique is required before these alloys can be used for specific purposes.

Research is being undertaken by many manufacturers at great expense and the public finally reap the benefit, but it would appear that in a matter of such vital concern to industry and the community more rapid progress could be made and a much bolder policy pursued if the public organisations and the large power distributing companies and authorities accepted the responsibility of the provision of funds for research. In the Universities much fundamental work can be done if funds are available. The Department of Scientific and Industrial Research has recognised recently the importance of the subject and is assisting industry and the National Physical Laboratory to carry out researches on the physical properties of metals at high temperatures. The metal problem, associated with the hope of higher efficiencies in heat engines, is also of very great importance in connection with 'low temperature' carbonisation of coal and other large-scale chemical engineering processes.

STRUCTURES.

The indebtedness of structural engineering to mathematics and to experimental science has already been suggested, but these powerful aids to progress had to be supplemented by the development of new materials and by a direct experimental attack before the remarkable achievements of recent times were possible.

In this respect it is well to go back occasionally to the work of William Fairbairn, who was president of this section in 1862. He carried out his classical experiments during the forties of last century to determine stable forms of compression elements for structures, and upon his experiments practice followed rather slavishly for more than forty years. The failure during erection of the cantilever of the Quebec Bridge dramatically forced attention upon the problem of the stability of compression elements. Again a series of experiments filled the gap in knowledge and led to success. Further work on a large scale, the cost of which can probably only be undertaken by public authorities, is desirable. During the last twelve years attempts have been made, with considerable success, to design all-metal aeroplanes and rigid airships, the compression elements and beams of which must of necessity be as light as possible. With a fair degree of precision the external forces can be determined by experiments upon models. The structure of an aeroplane has a certain degree of 'statical indeterminateness,' but the forces and the bending moments in the elements can be approximately obtained, and what might be called the primary stresses can be found with the same degree of approximation. Three serious difficulties immediately, however, faced the designers : (1) materials of a suitable character and in a suitable form for constructing the very light but strong elements, (2) the lack of technical skill and suitable machinery for building up the elements, (3) the lack of knowledge and the almost insuperable difficulty of determining by analytical methods the secondary, and what might be called stresses of even higher orders of indeterminateness. The only way was a courageous combination of experiment and mathematical investigation. The one without the other was useless, but by a combination of the two rapid progress was made, and to-day all-metal planes are being constructed of steel or of duralumin which are as light, more durable, and stronger than the planes made of the best spruce.

No new fundamental knowledge, such as the splendid contribution of Navier or of Euler to the theory of elasticity, has come out of the work, but taking these fundamental formulæ as faithful guides the experiments have led to the developments of forms which, allied to the ingenuity of skilful designers, have made it possible to build machines fully equal to the very onerous conditions of lightness, strength, and durability imposed upon aircraft. Fairbairn and Hopkinson, when experimenting on the forms to be adopted for the compression elements of the Britannia Tubular Bridge, were faced with almost the same difficulties, but their problem was simplified in one respect. They were able to use wrought-iron plates and angles sufficiently thick and rivets of sufficient diameter to make it unnecessary to consider the instability that may occur in the plates between adjoining rivets or in the web of the angles. This is not the

place, nor is there time, to consider in detail either the early or later experiments, but only to refer to them to illustrate how rigidly controlled experiments were essential to the development of metal bridges and aeroplanes.

There is still, however, a great deal to be done in connection with structures, and the only hope of a satisfactory solution of many problems is not simply by accumulating experience, but by combining experience, experiment, and mathematical analysis in an endeavour to reduce the whole to definitely co-ordinated knowledge. Nearly thirty years ago I was privileged to assist with some experimental work on the deflection of bridges produced by rapidly moving loads. They were incomplete, but they definitely indicated that the assumptions often made by engineers as to the effect of rapidly moving loads were not justified. In view of the publication in the early part of this year of the report of the Bridge Stress Committee, published by the Department of Scientific and Industrial Research, of which perhaps it is only necessary to say that it is worthy of its distinguished chairman, Sir Alfred Ewing, and his colleagues, it is fitting to particularly refer to this subject of impact on bridges.

As early as 1849, in the Report of the Royal Commission on the use of wrought iron in railway bridges, the subject was discussed and Sir George Stokes gave a mathematical solution for a load moving over a girder, but this solution was of little value in practice. Fore eighty years the effect of travelling loads has been treated in an empirical illogical manner and a number of impact formulæ, which the Bridge Stress Committee Report shows have no valid foundation, have been rather blindly used by engineers. The report shows very clearly that what is important is not the fact that the load is applied suddenly to the structure, but the possibility of synchronism or otherwise of the structure with the periodicity of unbalanced forces due to the engine or to other causes. Experimental data of the vibrations produced in the structure by the various types of moving loads have been carefully obtained and methods of analyses developed which have made it possible to determine with some degree of precision the true impact factors to be applied. Thus a problem of real difficulty, in connection with which doubt and uncertainty has probably led to expenditure far greater than the necessities of the case demand, comes within the possibilities of solution. The carefully conducted work of the Committee spread over a few years has given more precise guidance for future designers than a hundred years of practice. It may quite reasonably be said that practice in the past has led to safety. That certainly must always be the first consideration, but undue safety involving the use of too much material or even too narrow a margin of safety by using materials unsatisfactorily cannot be said to be good engineering, and engineers as well as the general public—for whom engineers are trustees—cannot be satisfied until all uncertainties that can be removed by careful scientific inquiry give place to more accurate knowledge. The only hope of completely solving this all-important problem, as well as the equally important problem of the distribution of load through various types of floors to the girders of both steel and reinforced concrete structures, is by direct large-scale and model experiments and by that type of co-operative action of the scientist and practical engineer which has achieved

such splendid success in connection with the work of the Bridge Stress Committee. It is also of interest to note that history has repeated itself in that the great contribution which Fairbairn made to structural engineering was only possible, as he himself admitted, by the co-operation of the practical engineer and the mathematician.

AEROPLANES AND AIRSHIPS.

The development of the forms of aeroplanes and rigid airships and the determination of the forces acting upon them—lift and drag—and the distribution of these forces, is another illustration of the splendid use that can be made of the combination of experiment and mathematical analysis. Following the fundamental principles of Newtonian Mechanics, dynamical laws of similarity have been developed which in combination with the wind chambers and the precise measuring devices used for the determination of forces and moments acting upon models have made it possible to anticipate certain of the forces acting upon machines. Other forces could only be estimated from meteorological data obtained from an examination of the velocity of upward and downward currents of air which a ship or aeroplane may suddenly encounter. Much could be said of the many other contributions of 'pure science' to the successful development of the aeroplane. Many of the details and instrumental equipment owe much to science, but success could not have been achieved if these gifts had not been supplemented by the application of the experimental method, in which precise measurement has played an important part, to the solution of the specific engineering problems associated with the engine and the structure.

MATERIALS.

Allied to the subject of structures is that of the strength of materials and their behaviour under various types of stress. For nearly seventy years experiments have been carried out to determine the effect of repeated stresses on metals, but the development of high-speed machinery during the last twenty years has focussed attention upon this important subject, and it is now realised how imperfect is our knowledge. A vast amount of experimental data has been accumulated and it has been clearly shown that the safe range of stress to which a piece of material can be subjected for, let us say, an indefinite number of times, depends in some way, not yet clearly defined, upon other and more easily determined physical properties. But it is not yet always possible to foretell that some element of a locomotive or of an aeroplane engine, or structure, or other machine will not fail under the conditions it has to meet in practice. Small discontinuities in the structure of wheel tyres, a surface defect in an axle, a wheel gripping very tightly on an axle at one section, surface cracks which cannot even be seen by the microscope on a wire used for a rope, or in the disc of a steam turbine rotor; the surface condition of a quenched and tempered spring used for a locomotive, an aeroplane engine, or a motor-car may lead to failure under the repeated stresses due to the normal forces acting upon the element, or due to repeated blows, such as, for example, a locomotive experiences whenever it passes over a rail joint, or

a motor-car along a road. Cam shafts for the stamping mills, used in the gold mines in the neighbourhood where we are, frequently fail, and engineers and metallurgists are often at a loss to give a reasonable explanation. The whole problem is bound up, not only with the physical properties which statical experiments are capable of testing, but apparently in some unknown way with the nature of the crystal structure of a metal; perhaps the stress that produces fracture depends upon the distribution of very small quantities of so-called impurities in the space lattice of the crystal, or upon the nature and properties of the material forming the crystal boundaries, and upon the surface conditions, including hardly perceptible corrosion, as well as the existence of other discontinuities incidental to the manufacture of metals. Some metals appear to fail by slipping on the crystal plane, and others by cracks commencing at crystal boundaries, or at surface discontinuities. To the metallurgists, engineers must unstintingly pay tribute for the splendid work they have done in supplying materials to meet the ever growing and exacting needs of modern engineering. By the careful scientific control which characterises a modern steel-works, thousands of tons of apparently uniform material can be turned out, but the engineer does not always use the materials as they should be used, and the metallurgist has not always the knowledge required to insure perfect reliability under the exacting conditions of service. These, allied to the difficulties to which reference has been made, make it imperative that in this problem of the reasons for failure of metals under repeated stresses and their prevention, the co-operation of engineers, metallurgists, physicists, and mathematicians must be enlisted; experience alone is by no means satisfactory.

Incidental to the failure of materials in service, the recognition of synchronism as an important contributing factor, and the assistance given by experiment and dynamical theory in anticipating synchronous speeds, has been of the greatest service in the design of modern high-speed machines. Crank shafts of aeroplane engines and of internal combustion engines have been known to fail in a few minutes because designers have failed to recognise the possibilities of synchronism. Such disasters can now be avoided in many cases.

ROADS.

Before concluding, I should like to refer to another subject of interest. The rapid developments of road traffic during the last quarter of a century has made the road problem one of considerable importance. From the point of view of the user and the community, the general policy of road construction, the capital expenditure involved, and the cost of upkeep are of primary concern. These are dependent upon the materials available and the use made of them. Incidental to the problem is that of vibrations produced in structures adjoining the road and the probable damage accruing from them, but of this there is only time to say that experiment is necessary to determine the importance of these vibrations on the materials of structures.

Reference has already been made to the lack of knowledge of the effect of blows and stresses due to vibrations in causing failure in metals, and the lack of precise knowledge which will make it possible to choose with assurance the particular material to meet certain circumstances. The

problem of road surfaces is in a large measure one not only of the suitability of materials to resist impacts but also of the prevention of impacts. An old philosopher, Desagulier, as long ago as 1714, argued with a direct simplicity worthy of a scientific man of eminence that a piece of glass could be struck many small blows without fracture, but one large enough would splinter it in pieces, and that a four-wheel waggon passing over a horseshoe might strike such a small blow that little damage would be done, whereas a two-wheeled waggon carrying the same load might destroy the road surface quickly. The problem might be slightly differently stated to-day, but in principle the difficulty is that suggested rather quaintly by Desagulier. Many experiments of actual road surfaces are being carried out in all parts of the civilised world, but considering its economic importance, the cost of upkeep of roads and the inconvenience of repeated repairs, it would appear that it would be well worth while, even though there may be doubt as to whether any definite and final conclusions can be reached in the laboratory, to let carefully but boldly conceived laboratory experiments direct the large-scale experiments much more than at present. If the history of other engineering developments is to repeat itself, only by such a procedure is the solution likely to be found. In many branches of engineering, materials and precision of finish have brought about remarkable developments and if, by close control of processes, plane road surfaces that will reduce blows to a minimum can be constructed of materials having a reasonable coefficient of friction, a sufficient degree of resilience and abrasive resistance, real advances may be expected. Steel, rubber and many other materials have been suggested; it may be that the chemist has by no means said the last word on the possibility of synthetic substances that will fill the bill, but, however that may be, whether in the direction of new materials or in the better use of materials that are available, it seems clear that road-making has become of such economic importance to the world that it should be removed from the category of 'trial and error' which for centuries has been the method of advance, and all the aids that science can give should be enlisted to achieve the desired end. It is not intended to suggest that science is not at present assisting. The chemist is controlling the manufacture of cements, so that products of great reliability are available from the various firms manufacturing cements; tars and bitumen and other materials of a mastic character are determined in consistency and properties by the control of physicists and chemists; india-rubber vulcanised under definite chemical control is being tested in road surfaces; certain substances like silicate of soda have been introduced as dressings to concrete; laboratory tests have been made in connection with concrete and other materials, but in the field concrete is not by any means made under that rigidity of control necessary for a product of known properties to meet particular conditions; it seems clear that many miles of main roads have been made of concrete, suitable perhaps for some purposes, but not of the mixture necessary to meet conditions of heavy road traffic. But in the direction of research for new materials, as well as in the control of the manufacture and of the properties of known materials and in the actual carrying out of the work in the field, science and the scientific method seem to be the necessary aids for future progress.

There is another aspect of the subject which is perhaps related more to economics than to engineering, but it nevertheless demands a definite scientific approach, rather than a policy of drift. I refer to what has almost become a contest between road and railway development. At home there seems no doubt that thousands of tons of heavy materials are carried upon roads, with some element of convenience, it is true, that should be carried on rails, at much greater gross cost to the community than if sent by rail. The calorific value of the fuel consumed per ton mile and consumption of other materials is greater for road than for rail transport, and the actual damage done to road surfaces and vehicles is much greater for the heavy loaded road vehicles than for rail vehicles. True it is that flexibility, direct delivery, and many other advantages are claimed for road traffic which may far outweigh the disadvantages just referred to, but a failure to visualise the problem of internal transport as a whole may lay unnecessary burdens upon the community. In the opening out of new country that may be the problem in South Africa. I venture to suggest that a courageous but, as far as is humanly possible, a 'scientific' policy of development by road and rail should be followed.

The argument of this address can be summarised into a few sentences. New epoch-making developments in engineering depend upon the discovery of new facts of science and upon materials and technical processes. The only hope of solving many of the problems which face the engineer to-day is by carefully organised experiment. Engineering is of such vital importance to modern life that not only manufacturers but large users, public authorities, and governments must be interested and provide funds for research.

In Great Britain a good deal of engineering research is being done by large firms, by research associations connected with certain industries, by the Universities and by the Technical Colleges, the National Physical and the Building Research Laboratories, which are under the direction of the Department of Scientific and Industrial Research. This Department also assists research associations by grants, and the Universities by the provision of research scholarships and research assistants, but at present it seems that sufficient research is not being done, and that not nearly enough researchers are being trained to meet the needs. How can the demands of the case be met?

It would appear that we must look largely to the Universities to train researchers. I suggested that I wished to avoid the subject of the training of engineers, but one word I wish to say and that is to refer to the necessity for the training in the Universities of a considerable number of engineering students with the research outlook. Training in strict habits of observation and in the investigation of problems theoretically and by experiment should form part of the work of all engineering students. Much of the theoretical knowledge that a young engineer requires to learn is now to be found in excellent textbooks and in current periodicals, and these he should be taught to read critically and with understanding, but he should also be taught to face all his problems in the spirit of an investigator. Certain selected students should be encouraged to remain at the Universities after graduation or to return after some experience of actual works to engage specifically in research. Engineering needs such men, some to give their

whole time to research while others carry the spirit of research into the ordinary problems of industry and engineering. Employers, public authorities, and governments must utilise this research ability, and more men should find their way into industry from the research institutions. The Universities, however, cannot do this most important work of training researchers unless they are adequately equipped and staffed to give members of the staff the necessary time for research and to devote themselves to the training of students in research. To this end sufficient funds must be provided from private and public sources.

In the time allotted to this address it has been impossible to do other than refer briefly, and perhaps unconvincingly, to the importance of research in engineering. It has not been possible to refer, nor should it be necessary, to the indebtedness of engineering to craft ability, upon which success so often depends. One word, however, should be said about the desirability of training engineering craftsmen to the appreciation of the scientific problems underlying their craft. When this can be done, and much more is possible than at present, it leads to an increase in efficiency and adaptability, to a greater tolerance and interest in new methods, and in the immediate task. It also leads them to appreciate the relationship of their problems to the great world of nature, and thus to a widening of that interest to which the work of this association is directed.

The engineer is faced with many unsolved problems. Nevertheless he must find immediate, if only approximate and tentative, solutions to many of them, and in the solution he often has to deal with many types of men. If experimental science and mathematics cannot give him an exact solution he must still carry on, and in this way much has been achieved. It is for this reason that the engineer has to learn much by actual experience in the workshop, in the field, and frequently he becomes impatient of science and lays too great emphasis upon experience. Manufacturers wish to see returns upon their capital and remuneration for their energy, but as an effective guarantee of future progress and in the solution of many problems in design, in processes, in materials, as well as in the discovery of new methods, it is necessary, as Francis Bacon would to-day remind us, 'to apply natural philosophy to particular problems and particular problems must be carried back to natural philosophy.'

SOUTH AFRICA'S CONTRIBUTION TO PREHISTORIC ARCHÆOLOGY.

ADDRESS BY

HENRY BALFOUR, M.A., F.R.S.,

PRESIDENT OF THE SECTION.

THE interest which is manifested in the study of the early chapters in the story of Man's culture development is steadily increasing, not only in intensity but also in range, and there are now but few regions which remain totally unsearched for traces of early Man and of his material activities. Interest becomes more *intense* as the scattered material is found more and more to belong to one huge complex problem, and it is realised that each scientifically collected item has a place in the cosmic mozaic, and may be the means of illuminating what has hitherto been obscure. The ever-increasing geographical *range* of this interest results largely from the discovery that from most parts of the world there may be collected data having a bearing upon these problems, and that it is profitable to search for traces of early Man in almost any area which has ever been habitable.

The sources of information from which Man's early culture-history may be elucidated are mainly twofold. On the one hand there are the actual relics of antiquity, which are revealed by the spade of the excavator, and whose relative position in the chronological sequence is determined by their position in the deposits in which they are found, and by their associations. From these the culture timetable must be plotted out. On the other hand there are important data to be derived from the study of those living races and peoples whose progress has been arrested or retarded, and who have persisted in a condition of more or less backward culture. From these stagnating populations there is much to be learnt of importance to the archæologist.

Prehistory may be described as the study of culture-fossils—the remains of high antiquity which have been preserved for us, and consist of the less perishable objects and materials, such as have successfully resisted the ravages of time and its allies of destruction. But, just as the incomplete fossil remains of extinct animals can be diagnosed and made 'to live again' by comparative study of recent forms, so, too, may many of the gaps in the archæological record be filled, at least suggestively, by the study of the 'unrisen' peoples who have in so many instances remained in their Stone-age, from which they have never emerged unaided. The living Stone-age may go far towards illuminating the obscurities of the ancient Stone-ages. To achieve the most complete results, in building up the story of Man's past, prehistoric archæology and ethnology must co-operate as syndical sciences, each serving to elucidate the other's mysteries.

Unfortunately, the exceptional opportunities for study which have

been offered by recent primitive peoples have largely been neglected, and the scientific value of close research into their material culture has usually not been recognised until it was already too late to reap the full benefit of the harvest. Civilisation has been more concerned with the extermination or rapid metamorphosis of primitive peoples and their industries than with their scientific investigation; and it is one of the tragedies of pre-history that so much of the invaluable and once accessible material should have been allowed to die away unstudied.

Such a people as the native Tasmanians might have thrown a flood of light upon some of the problems of the Middle- and Late-Palæolithic culture phases, had their stone-working technique and their uses of particular types of implements been investigated, as they might have been, while still being practised under conditions which had persisted throughout many millennia.

The opportunity was missed. Seventy years from the date of the first European settlement in Tasmania the indigenous race had been completely wiped out, not one survivor remaining! The very scanty inquiries into the habits and industries of this most interesting primitive people, conducted before their extermination, must now be supplemented by researches following the methods of prehistoric archæology. The chance of studying a living palæolithic people has passed unutilised, and both the ethnologist and the archæologist are left wondering, with the philanthropist, why such things are allowed to happen.

This brief reference to the Tasmanian aborigines may seem to be a digression from my subject. But, in the history of South African colonisation, there may be noted a somewhat similar failure to seize an opportunity of investigating fully a living primitive culture which might have thrown much light upon culture-details of long-vanished peoples elsewhere.

The Bushmen and their kindred, although culturally less primitive than the Tasmanians, none the less afforded an example of persistence of palæolithic conditions into recent times. Their culture was a purely Stone-age culture, and they made and used stone implements of types many of which recall forms of implements which prevailed during the earlier section of the Late-Palæolithic culture-phase of Western Europe and North Africa. The functions of the implements of the ancient series have been diagnosed as far as possible, and terms have been assigned to them, indicative of their presumed uses; but this is largely guesswork. Some degree of certainty, however, might have been reached had the living users of identical types of tools been closely studied, while the opportunity lasted, and had the details of manufacture and use of the various tool-types been placed on record.

Again, it is too late for that record ever to be made complete and, from an archæological point of view, enlightening. Dispossessed of their old hunting-grounds, the miserable remnant of the once virile and widely dispersed Bushman race is rapidly passing away under environmental conditions so altered from those formerly enjoyed, that but little light can be thrown by the struggling survivors upon the true characteristics of Bushman culture. The old camp-sites, now deserted, must be investigated archæologically; and, in diagnosing the relics discovered, inference must take the place of direct observation.

It is true that valuable material for the study of Bushman culture—their habits, traditions, legends, &c.—has been collected and is available, thanks to the enlightening researches of William Burchell, Lichtenstein, Baines, Miss Lemué, Campbell, Chapman, Dr. Bleek, Orpen, Stow and others who collected first-hand data, and the work has been ably followed up by Miss Lloyd and Miss Bleek. But information regarding the uses of particular types of stone implements and the technique of their manufacture is disappointingly meagre, and valuable clues to diagnosis have been denied to us. Even that most striking feature of all, among Bushman relics, the rock-paintings and engravings, some of which are of very recent date, must be studied archæologically, on similar lines to those pursued in the interpretation of the strikingly similar artistic achievements of Aurignacian and Madeleinean Man in France and Spain. How greatly would the interest of this prehistoric art in Europe have been enhanced if only a fuller comprehension of Bushman art had been arrived at by direct observation of its processes and functions. The artists have gone; this chapter in art-history is now closed, and there can be no period of *Renaissance*. The modern commentary is appended to the descriptive chapter in the form of suggestive footnotes and appendices, offering tentative interpretations, of which some are extremely plausible and well founded, while others, it must be confessed, are the products of imaginations far more vivid than are the colours and the realism of the actual paintings discussed.

At the same time, while we must admit that the ethnological record is far weaker than it should be, through lack of scientific observation on the part of those pioneers who had opportunities of detailed study, we can note with great satisfaction the steady growth in South Africa of a keen interest in the archæological problems with which the country teems. The progressive development of local attention to the study of the Stone-age in South Africa, the increasing desire for the establishment of a time-sequence of culture-phases, coupled with the adoption of more precise scientific procedure in research, are features in the intellectual activity of the region whose progress towards maturity I have myself to some extent been able directly to observe and follow.

This is my fifth visit to South Africa, and I have thus had opportunity of observing successive episodes in the story of the awakening of enthusiasm in regard to one of the region's most valuable assets—its unlimited wealth in material for the study of prehistory.

My first visit, in 1899, exactly thirty years ago, revealed to me that, although a definite start had been made and collectors were in the field seeking for relics of the Stone-age, this pastime was restricted to comparatively few enthusiasts, and the search was of a somewhat desultory nature, conducted without strict method or well-defined perspective outlook. The work had, indeed, been excellently initiated long previously by T. H. Bowker, in 1858, and had been followed up by Dr. Langham Dale, E. L. Layard, and E. J. Dunn, about 1868, by John Sanderson, in 1876, by J. C. Rickard and W. D. Gooch, in 1880, by Major H. W. Feilden, about 1881, and by various other pioneers. These had already done much to show how rich was the material, and had suggested correlations with the ancient industries of early prehistoric Europe.

My second and third visits, in 1905 (when the British Association met here for the first time) and in 1907, showed me that there were already many workers in the field, and that increasing attempts were being made to study the finds stratigraphically and to classify them in accordance with sequence-dating. Still, the work of correlation was hampered by imperfect acquaintance with the results arrived at by European archæologists. This limitation led to some deductions which were hardly justified by the facts.

In 1910 I again found myself in South Africa—by invitation of the South African Association. It was at once manifest that there was an increasing recognition of the importance of the geological associations of the earlier types of stone implements, as a means of establishing their relative antiquity and the ordered sequence of their succession. More serious attempts were being made to investigate ancient alluvial deposits and to record the particular strata from which implements were derived, and the depth within the strata. The archæological collections in the various museums were beginning to be grouped and arranged so as to tell a definite story—the story of the occupation of South Africa in early times by successive waves of immigrants, each wave introducing more or less distinctive culture elements. In this way, the museums were not only attempting to furnish a summary of local archæological phenomena as interpreted up to date, but they were also offering suggestions as to the aims and objectives of future field-research, and indicating the nature of the problems awaiting solution. It was already abundantly clear that the time-honoured aphorism '*Ex Africâ semper aliquid novum*' required supplementing with a rider to the effect '*non nunquam, saepissime etiam, et aliquid antiquum.*' There was abundant stimulus to field-workers.

This year it is my privilege to renew acquaintance with South Africa, whose attractions, be they scenic, zoological, archæological or ethnological, ever draw me with magnetic force. My gratification is extreme. Not only have I the longed-for opportunity of revisiting scenes full of interest and beauty, but I have an additional source of gratification in the privilege of having been invited to preside over that Section of the British Association whose concern it is to aid in revealing the great epic story of human progress, both physical and cultural. It is a very great pleasure to note the strides which have been taken since my last visit, nearly twenty years ago, towards unravelling the local archæological complex, and to note that this pursuit of knowledge is conducted on increasingly methodical and scientific lines.

It is manifest that the vast African area lying to the south of the Zambesi holds almost unparalleled wealth of archæological material. It appears as an inexhaustible mine of ancient relics. This is, probably, largely due to the successive waves of immigrant peoples having arrived in early times from the North. South Africa, though spacious, is a *cul de sac*, a land-terminus beyond which stretches the southern ocean, which arrested any further southward dispersal. We must picture the arrival, one after the other, of primitive peoples in various stages of culture-advancement, and it is natural to assume that the order of their arrival in the far south is indicative of their general culture-status. The more undeveloped peoples, less capable of defending their rights and of holding

their own, yielded to the pressure of the more progressive peoples, before whose advance (due probably to similar causes) they gave way, eventually being forced down into the *cul de sac*, whose abundance of game animals, no doubt, afforded compensatory attractions, and where they could establish and maintain themselves unmolested, until a new immigration brought a fresh racial stock into the region and renewed the clash of cultures.

During long ages, this sequence of irruptions of peoples inevitably induced a resultant congestion of heterogeneous ethnic elements, the weaker units continually giving way to the stronger, who, it may be reckoned, partly absorbed and partly exterminated the earlier occupants. The existing cultures must, at least, have been influenced and altered through contact with the new. Thus it is not difficult to see how, through a long sequence of immigrations into a region devoid of outlets, vast quantities of the more imperishable culture-relics came to be accumulated in South Africa. It is also clear that the inevitable overlapping of cultures, coming into enforced contact in this Ultima Thule, tended to result in not only fusion but also confusion, and to bring about complex, hybrid industries, whose parentage it is the aim of local archæologists to unravel.

The process of sorting out the data, and of classifying and evaluating the Stone-age cultures represented in South Africa, is now proceeding apace, thanks to many keen researchers. Already several new names have been at least tentatively adopted for denoting various differentiated industries, which have been provisionally assigned their places in the chronological series. The earlier attempts, by Gooch and others, to reduce the material to some kind of classificatory order, had been followed rather more intensively and with varying success by J. P. Johnson and L. Peringuey; and within the last few years, in addition to numerous important papers by various authors in the scientific journals, the Rev. Neville Jones has published a very interesting book on the 'Stone Age in Rhodesia' (1926). More recently still, Mr. M. C. Burkitt has dealt ably and suggestively with the general subject in his volume on 'South Africa's Past in Stone and Paint' (1928), in which he has summed up the more important results so far obtained by field-research, and details the impressions which he derived from an extensive tour of inspection made at the invitation of the University of Cape Town. This volume will, no doubt, prove a useful guide to collectors, and an incentive to systematic excavation. A basis is suggested upon which scientifically collected material may be tabulated. Incidentally, Mr. Burkitt has indicated in no uncertain manner how exceedingly abundant is the material and what a vast and interesting field of inquiry is open for future research in South Africa.

This valuable archæological mine has as yet been only partially exploited, but its potential wealth is unquestioned; and, although prehistoric archæology must rank as a 'pure' science, and cannot be regarded as one which materially increases the *financial* welfare of the community, the finds which its pursuit brings to light must be regarded as a valuable asset to the country, worthy to be ranked with gold and diamonds and other commercially-productive assets. The dividends resulting from the scientific exploration of the archæological mine, if not to

be declared in £ s. d., are such as cannot fail to bring credit to the country. *Kudos* in place of cash—a not unworthy alternative!

The great scientific importance of this valuable heritage imposes certain responsibilities upon the Administration. Organisation in research is very desirable, and, although it is undesirable to curb the enthusiasm of untrained collectors, who may help very materially, it is to be hoped that, as far as possible, the field-work may be conducted under the advice and, when possible, the *surveillance* of properly trained and qualified archæologists, who may ensure that scientific methods will be pursued. This will render the finds collected more reliable as evidence, suitable for co-ordination, and capable of serving as material for building up the early human history of the region. The appointment of a carefully selected advisory committee would appear to be a practical measure, and might prevent much unprofitable work. A valuable archæological site may so easily be spoilt and its interest permanently destroyed by the unmethodical fossickings of untrained enthusiasts, who would be better employed if they restricted their efforts to collecting *surface* specimens. Many important sites have already been rendered useless for systematic excavation through unmethodical disturbance of their stratified deposits by persons whose sole objective has been the acquisition of objects, and who have neglected to record the *data* which, if carefully noted, would have given real interest to their finds. A single site methodically investigated has far more value than a dozen unsystematically exploited.

Surface finds are very frequently of importance to the prehistorian, particularly when accurately localised, but it must be remembered that their interest is *derived* and not intrinsic. Their value to science depends upon the possibility of comparing them with similar types whose chronological horizon has been ascertained with certainty from their position in undisturbed stratified deposits. Material, form, technique, patination and abrasion, all have their significance when surface finds are collated with those of determined provenance. Science makes exacting demands from its votaries, and archæological research is no exception. The difficulties and complexities involved in investigations of the earlier phases of human culture furnish, indeed, one of the chief attractions of this line of research, whose results vary in their importance with the degree of care exercised in obtaining them.

When one is engaged in research-work, there is undoubtedly a fascination in following up a theory already formulated, and in seeing the newly discovered material fitting into the theory and supporting it. But it must be admitted that there is danger in this attractive procedure, since preconceived ideas tend to restrict and cramp the outlook of the investigator and to bias his mind, causing him to overlook evidence which may be of considerable significance. At the present time, it is not so much abstract theories that are wanted as concrete facts—unassailable facts, ascertained by close scrutiny of ancient alluvial deposits upon ancient camping-sites, in caves, under rock-shelters and so on. From these in time will be established the relative antiquity, sequence-position and characteristics of the early industries represented in South Africa; their geographical dispersal, the probable routes of their migrations and their inter-relationships. Also the effects of the successive impacts of newly arrived

cultures upon those already established in the region will be rendered clearer when more detailed and precise data have been secured and can be co-ordinated.

Problems still awaiting solution abound in South Africa and call for the onslaught of skilled and unbiassed investigators, who are prepared conscientiously to modify and even jettison theories already propounded, if new facts call for this sacrifice. Diagnosis gains by being cold-blooded and impassive, and is the more sure if the domination of preconceived ideas is held in restraint.

One of the problems in which I am myself keenly interested is that afforded by the Stone-age remains which are so abundant along the Zambesi and its tributaries in the neighbourhood of the Victoria Falls. The first stone implements from that district to be brought to notice were, I believe, collected by Mr. A. J. C. Molyneux; but many others have since been obtained on the spot by Dr. Lamplugh, Mr. Franklin White, Colonel Feilden and others. In the course of three visits which I have paid to the Victoria Falls—in 1905, 1907 and 1910; collectively amounting to a stay of thirty-seven days—I collected some 1,200-1,300 implements and artificial flakes of chalcedony and quartzite. The numerous well-defined implements are, with very few exceptions, of pronounced Lower-palæolithic *facies*, Chellean and Acheulian, and, but for the material of which they are made, they might almost as well have been obtained from the terrace-gravels of the River Thames or of the Somme. That is to say, in form and technique they are absolutely comparable with types which characterise the 'River-drift' cultures of Western Europe. They might be taken to indicate a late survival of these culture-phases, which had persisted until relatively recent times on the periphery of their dispersal. Or they may be regarded as an independent genesis of similar cultures, unconnected with the northern series, and evolved in response to similar environmental dictates. But evidence of very considerable antiquity is afforded by the implements themselves, which are often heavily abraded and patinated and frequently very highly glazed.¹

Still more important is the position in which many of the implements are discovered. I have found some imbedded at various depths in old alluvial deposits along the banks of the Zambesi, and of the Maramba and Masui tributaries; others were associated with or imbedded in thin gravel drifts scattered over the bare basalt plateau below the line of the Falls. This plateau is the ancient bed of the Zambesi over which the river flowed before, by gradual recession of the Falls to their present position, the upper portion of the Batoka Gorge had been eroded.

If we are justified in assuming that the implementiferous gravel-drifts distributed over the ancient river-bed and now lying 400-600 feet above the present level of the river in the gorge, were deposited there by the Zambesi itself, then there is direct evidence not only of antiquity, but of extremely high antiquity. Lamplugh, who carefully surveyed the Batoka Gorge in 1905, A. E. V. Zealley and several other skilled geologists have

¹ The nature of the peculiar and very intense 'glazing' in this district has not, believe, been finally diagnosed. It appears to me likely that it results from deposition of silica from silica-charged water (perhaps spray) which evaporated rapidly from the hot, exposed surfaces of the chalcedonic implements.

expressed themselves more or less decidedly in favour of this view, which certainly coincides with my own impressions. Assuming this impression to be correct, it is evident that, since these gravel-drifts, with some of their associated artefacts, were deposited upon the ancient river-bed, the river has eroded out a channel to a depth of from 400 to 600 feet through solid basalt. The great depth of this wonderful gorge affords data for estimating the time required for this gigantic work of attrition, while the extent of the canyon above the gravel-drifts supplies further measurable time-data.

Now, such important evidence of Man's antiquity in South Africa deserves very careful scrutiny. It is worth while establishing once for all and conclusively whether the gravels referred to *were* laid down by the Zambesi itself, and not by lateral spruits. In spite of the prevailing geological opinion, one must recollect that Dr. Codrington, and possibly some others, did not accept this view, and, while any possible doubt remains, further investigation is called for by highly competent geologists, who can make an authoritative pronouncement. The problem is one well worth solving and I would express the hope that its solution may be an objective of geologists, who alone can decide the point at issue, and who will, by so doing, earn the gratitude of their colleagues the archæologists, since this problem is the key to several others.

The detailed geological diagnosis of the implementiferous terrace-gravels throughout the South African region would be of great benefit to archæologists, who are endeavouring to group the early stone implement types into a time-scale sequence. Some good work has already been done, but further research is needed before the succession and inter-relationships of the earliest cultures can with confidence be demonstrated.

One of the most interesting questions for local archæologists to answer, is the true culture-horizon to which the industry of the so-called 'Still Bay' culture should be assigned. It is characterised chiefly by the fine and shapely leaf-shaped blades, many of which are flaked all over with considerable skill. These form a decidedly specialised group. The industry appears to be somewhat local and not to be widely dispersed. It was one of the earliest distinctive industries to be noticed, and came into prominence as early as 1866, when Dr. Langham Dale collected many examples upon the Cape Flats. One wonders, in fact, why Still Bay should be regarded as the 'type site' of this culture, since, by the rules of priority in nomenclature, the designation 'Cape Flats' industry would appear to be more appropriate, in recognition of Dr. Dale's pioneering discovery. But this is by the way. By some, the dominant implements of this industry have been taken, on insufficient evidence it seems to me, to indicate a Solutréan phase in South Africa. J. P. Johnson described the leaf-shaped blades as 'Solutric,' and L. Peringuey refers to them as exhibiting a 'Solutrian *facies*,' though there is a non-committal touch in his expressed opinion, since the chapter which deals with this industry is headed 'The Neolithic'! It appears to me that the technique of the leaf-shaped Still Bay blades differs considerably from that of the typical Solutréan blades of Western Europe, and hardly justifies any confident suggestion of affinity. It will be extremely interesting when the exact status of the 'Still Bay' or 'Cape Flats' culture is established, and when

it is known whether it was locally-evolved from a previous indigenous culture ; or whether its origin is due to 'mutation,' as a result of culture-fusion ; or, again, whether it represents an intrusive culture which had been differentiated elsewhere.

Another intriguing problem has as its focussing point the '*kwè*, the stone digging-stick weight of the Bushmen. Although this is one of the best-known implement-types in South Africa, and one of the most widely dispersed, it presents one of the greatest puzzles. Judged by the standard of Europe and of most other parts of the archaeological world, the perforated stone ball known as '*kwè* seems to be out of place in the hands of a people whose culture largely suggests palæolithic affinities. The art of perforating implements of hard stone was, in Europe, a late development, and it does not appear to have become prevalent until the later phases of the Neolithic period. Hence, there is a suggestion of precociousness on the part of the Bushmen, whose general status hardly warranted their possessing, or, at any rate, making perforated stone tools. The question as to how they came by this technique is one which is not readily answered. A possible solution occurred to me many years ago, when I ascertained that another people, occupying an area in North-eastern Africa, employ a practically identical implement—to wit, a simple digging-stick heavily loaded with a perforated stone weight, through which the stick passes. These people are the Gallas, an Hamitic people domiciled to the south of Abyssinia. Being in a relatively advanced state of culture, *their* employment of perforated stones is not in any way remarkable. But their use of this stone-weighted digging tool does suggest the possibility that, in the course of their southward drift, some of the Bushman hordes may have come into contact with the Gallas, or kindred peoples, and have acquired from them a knowledge of this tool, and of the technique involved, and have carried with them into the South a borrowed idea which was destined to become an anomalous though prominent feature in the so-called 'Wilton' industry. That they should have invented the '*kwè* for themselves is contrary to analogy, and the fact that an identical appliance, used in a similar manner, occurs among a people in the North, at least offers a possible explanation of the seeming paradox.

The existence in South Africa of the '*kwè*, with its marked *neolithic facies*, is rendered the more striking when we remember that implements of distinctively neolithic character are rarities in Africa to the south of the Zambesi. Ground stone celts, for example, are of very uncommon occurrence, and the same applies to the typical late Stone-age arrow-heads, locally found examples of which probably hardly exceed half a dozen in number. Other characteristic neolithic types are conspicuous by their absence in the region. In the local sequence of cultures the typical late Stone-age appears to be missing, or at least so faintly represented that it cannot be regarded as ever having exercised a dominating influence. At best the latest purely Stone-age culture definitely represented in South Africa suggests a general upper Palæolithic and Mesolithic level modified by a very slight infiltration of neolithic intrusion, and no marked invasion of a people possessed of a culture at all comparable with that of typical Neolithic Man in the north seems to have occurred.

When the great succession of invasions of Bantu peoples was inaugurated, the newcomers were, presumably, already well advanced in their Iron-age, and had long since passed out of even the latest phases of the Stone-age. Hence, as far as South Africa is concerned, the transition from Stone to Iron was remarkably abrupt. There is a marked hiatus due to the absence of linking cultures between a late Palæolithic phase, somewhat modified by intrusive ideas, and an already evolved phase of Metal. The fact that the later arrivals upon the scene—with their superior physique and their knowledge of working iron—were vastly superior to the peoples whom they overran and succeeded in dominating, must have created a sudden and far-reaching change in the general economic development of the region. The unbridged culture hiatus is a wide one, and is one of the striking features in South African history.

The earlier nomad hunters appear to have been gradually forced into their final southern home, and to have remained for a long time in a state of partial stagnation, undergoing comparatively little progressive evolution. To a considerable degree the industries which were successively introduced by them offer analogy to some of the early Stone-age industries which have been differentiated and standardised in Europe, and which furnish the obvious basis of comparison in prehistoric archæology. In all probability the early cultures of South Africa may, for the most part, be regarded as related to and as offshoots from those whose sequence-status has been determined in the north. But one cannot expect the resemblance between the European and the South African series to be very exact, since it is highly improbable that their occurrence in the two widely separated regions synchronised. A migrating culture, even the most unprogressive, cannot long continue unchanged. It is plastic and reacts to new environmental conditions, which create special wants and impose modifications. New elements appear in response to new demands, and some of the old characteristics vanish as their utility ceases. On the periphery of its dispersal an industry is, in fact, liable to show marked differentiation from its original prototype. Certain elements in the complex persist, and continue to supply evidence of affinity with distant cultures; but the points of divergence are no less interesting, since they illustrate the effect of the new environment upon the habits of the people. South African archæology intriguingly suggests culture-affinities, far-ranging both in time and in space, and illustrates at the same time how those affinities have become more or less obscured and attenuated in the course of long migration.

At present the South African problems have to be studied to a great extent as a group of isolated phenomena, because a vast area to the north remains, archæologically, almost unexplored. Northern Rhodesia, Nyassaland and Tanganyika Territory, when the story of *their* ancient cultures has been fully revealed, should throw a flood of light upon South African archæological peculiarities, by furnishing evidence of the migration-routes and of the gradual changes in culture detail resulting from the dispersal southward. Further north, in Uganda and Kenya Colony, important and suggestive work has already been carried out by Mr. E. J. Wayland and Mr. L. S. B. Leakey, the results of which have an important bearing upon the South African problems. But the full import and significance of

the north and south affinities and dissimilarities will be realised when the huge intervening area has revealed its archæological secrets and contributed its data for a valuable chapter in the story of the wanderings and sojournings of migrant peoples in the course of their progress southward.

In the meantime South Africa may well concentrate upon her local prehistoric problems, and proceed with the exploration of her past and the disentanglement of her sequence of bygone industries. This work is being actively pursued, and, thanks to the enthusiastic labours of Mr. C. van Riet Lowe, Mr. A. J. H. Goodwin, Colonel Hardy, Mr. J. Hewitt and many other keen researchers, the scattered threads are being gathered in and marshalled into orderly groups, and are beginning to be woven together into a compact and substantial fabric. That fabric, when completed, will be a record, representing the early history of primitive culture in the region, as based upon concrete facts.

Such research into the past is surely worthy of every encouragement from the universities, and deserving of Government benediction and even financial support. The material appears to be extraordinarily rich, almost inexhaustible, in fact, and the deductions drawn from carefully verified data in one district can be checked and re-checked by information culled in others, so that the final summing-up should prove authoritative and highly instructive.

It is recognition of the fact that this vast heritage of archæological material will prove a national asset of great importance, together with a feeling of gratification at the strides which have been made towards compelling this ancient bequest to yield a scientific dividend, that has led me to devote the address which it has been my privilege to deliver to the Section, to reviewing briefly a few of the factors and issues of South African archæology, a theme whose popularity will assuredly grow as people realise more and more not only its intrinsic local interest, but also its important bearing upon world-wide archæological phenomena, the study of which is steadily revealing the progression of successive culture phases which formed, layer upon layer, the foundations upon which were built the higher civilisations.

SECTION I.—PHYSIOLOGY.

PHYSIOLOGY THE BASIS OF TREATMENT.

ADDRESS BY

PROF. W. E. DIXON, M.A., M.D., F.R.S.,

PRESIDENT OF THE SECTION.

THE ultimate aim of medicine is the prevention or cure of disease: this practical aspect so far dominates all others that it is often referred to as the healing art; indeed, it is difficult to think of medicine apart from treatment.

The term 'physiology' is usually used to designate the science of function, whether it is studied in broad outline and dealing with the mechanism of action or as the physico-chemical mechanisms leading up to this action. Disease means the unusual functioning of tissues which may be the result of accident, hereditary weakness, or parasitic organisms. Generally it is wrong to speak of this as malfunctioning: the unusual functioning is physiological and perhaps the best for the organism under the unusual conditions. The science of medicine then is nothing more than trained and organised common sense based on physiology. It is still usual to speak of it as an inexact science; this is obviously wrong since medicine uses the same methods as every other science and the results of observation are as definite as those of the chemist or physicist, although it is true that in the complexity of the problem with which the physician may have to deal all the conditions of importance may not be known and the results of an investigation though correct for the conditions under which it is undertaken may be misleading.

But it is not with medicine as a whole that I wish to direct your attention to-day, but only with that part of physiology which forms the basis of treatment.

When the sciences of physiology and pathology a century ago passed from the realms of natural history to deduction and experiment, they naturally attracted the more original and eager minds in medicines, and the text of the writings of the nineteenth century deals with changes in structure and function. Treatment became neglected, the old shibboleths and rituals of treatment which had held sway for centuries were discarded, and there was nothing with which to replace them. In the middle of the last century S. Skoda and K. Rokitansky (in Austria) perfected a system of physical diagnosis which has had a practical bearing on medicine ever since. Skoda made many experiments with drugs on the patient without any expectation of producing benefit; the patients were not improved and Skoda thought it mattered little how the patient was treated. It is right to say, however, that these experiments were deficient in many respects according to modern views. At this period

the Vienna School held a prominent position in scientific medicine and the new doctrine rapidly spread. The physician studied disease in the patient: its beginnings, its progress, its effects, and the scars it left, as shown at autopsy. Scientific medicine looked askance at treatment; textbooks spent many pages in describing the symptoms, diagnosis, and pathology of disease, but two or three lines dismissed the treatment: and even in our times the 'scientific' physician is apt to be a diagnostician rather than a healer. The study of disease as an entity was the object aimed at, and a complete case was one which went to autopsy. That most admirable and popular textbook of medicine by the late Sir William Osler was typical of the textbooks of the time. Dr. Simon Flexner once told me that Osler's book, characterised by its almost complete lack of indications for treatment, was largely responsible for the Rockefeller millions given to medicine. The textbooks of the period told with considerable precision what was happening in the body during disease and what was likely to happen, but little or nothing on prevention. This state of affairs was unavoidable; there was no specific treatment, there was no science of treatment, for such a science could only come into existence when physiology and pathology had reached some degree of precision. Diagnosis was then and is now far ahead of treatment; diagnosis is often accurate where there is no satisfactory treatment and yet diagnosis is only a means to the end.

The science of treatment or pharmacology is therefore relatively new; it includes knowledge of all kinds dealing with the treatment of disease or alleviation of suffering. It is the climax of physiology and pathology, devised to subserve a practical end, and forms an important part of the great biological topic of the influence of conditions on the living organism. Few drugs now exist the mode of action of which is not understood, and the goal is not so far distant when it will be possible to introduce into the animal economy a factor which will exaggerate or retard the function of any tissue or collection of cells in the body, leaving the others unaffected; and most of these results have been obtained by the methods used in experimental physiology.

The first object of science is to ascertain facts: certain facts in physiology are relatively easily ascertained, those, for example, which involve the behaviour of ferments of isolated cells or of tissues and which require well-known chemical or physical methods. Other facts involving the physiology of the whole organism are more difficult to interpret, though they are the basis of the therapeutic side of medicine. More and more is physiology being regarded as the application of physics and chemistry to the phenomena of life. It may, of course, be argued, as I believe Descartes did first, that the body of a living man is a machine, the actions of which are explicable by the known laws of physics and chemistry: and that, therefore, the correct way to study physiology is by applying these sciences to the cell. I am by no means averse to the vast amount of academic research on these lines which is published annually, often by workers with little biological knowledge or training, but it surely should not precede the more immediate practical aspects of the subject. The modern attitude is expressed by a distinguished young biochemist who, in reviewing a well-known book on chemo-therapy in 1928, asks

'Might not the time and resources spent on chemo-therapeutic research be diverted more profitably to the study of chemical and physical mechanism?' The same attitude is reflected in the awards of Fellowships and Scholarships for Medical Research. Formerly all the recipients were primarily biologists with a medical training: now a medico-biological training is unusual. Physiology in the broad sense in which it was used by Claude Bernard and Huxley has given place to a new physiology of physico-chemical reactions: I might go beyond this and say that physiology is getting further and further from practical medicine, and this is the more regrettable as most of the Chairs in Physiology are connected with the Medical Schools and because the science of treatment is largely dependent on experimental physiology. Prof. J. S. Haldane clearly had this in mind in 1923 when he wrote: 'We may say without serious misrepresentation that the official present-day view of physiologists is that physiology . . . aims at investigating the physics and chemistry of life, and might properly be called biophysics and biochemistry.'

Biology has lost ground as an educational subject in the last twenty years; yet few, if any, sciences cultivate the powers of observation to the same degree. Universities, like London, in which biology was once compulsory for all undergraduates reading science, have now made it an optional subject for science degrees; so that it is not surprising to find not only the general public but men who have had a scientific training living in complete ignorance of the elementary laws which govern animal life, including their own. Can it be wondered at that we, as a nation, are the prey of the charlatan and food vendor? Ought not all educated people to know enough of biology to understand something of its methods and to have grasped its fundamental truths, if it be but to protect themselves? In our education and culture in this respect we fall short of many European countries and of America.

No branch of experimental biology has received less consideration in Great Britain than that of pharmacology: it is also the most neglected branch of medicine, and although the object of medicine is the healing of the sick, it is amazing that medical schools in Britain, often equipped with all other modern laboratories, lack departments of therapeutics. I was once asked at a meeting, by a leading medical man, what has pharmacology ever done? The answer is, of course, that it has formulated and brought reason and knowledge into treatment of the sick; so much did it impress that great pathologist, Ehrlich, that he left his sera and turned his attention to drugs, and with the unlimited resources at his disposal gave the world, amongst other drugs, salvarsan: so much did it impress the brilliant French chemist, M. Fournau, that he has confined his studies to those of drugs, a study which has resulted in the synthesis of many valuable arsenical compounds and dyes. In America many centres, including the Rockefeller Institute, have turned to the study of drugs; and Italian pharmacology is doing the same.

I have heard it said by a leading official of our Ministry of Health, speaking to panel practitioners, that they, in the Ministry, do not want stereotyped prescribing in treatment. Surely there was never such nonsense. If there is a best treatment, let us have it whether it is stereotyped or not. In this respect the British Medical Association has given

the profession a lead and shown by the experience of a great number of doctors that there is a best way of treating varicose ulcer in which the patient gets well quicker than by other ways, an advantage both to the patient and to the community who have to keep him whilst he is unfit for work.

The British physician is a skilled diagnostician and is in the forefront in all that pertains to this subject. The literature is so extensive that it is impossible for the average clinician to do more than this. But how few of them do, or perhaps the more correct word is 'can,' occupy the same time in the study of recent advances in general therapeutics? The successful physician has, generally speaking, to be content with such references to treatment as are to be found in clinical reading. The general physician must always be a necessity for diagnosis; but the details of treatment of patients will, I believe, in the future be handed over to those who have made a special study of the treatment of that particular group of diseases from one of which the patient is suffering. This is already the position in tuberculosis.

But the advent of institutions for experimental therapeutics is upon us, though Britain has taken little part in the movement. In this connection we welcome the magnificent buildings of the University of Capetown, and when the new hospital with its medical school is completed I confidently anticipate that adequate accommodation will be provided for that important branch of applied physiology, pharmacology, and that this will include laboratories of physiology and organic chemistry, which must be in close and direct association with the wards. The enormous importance of one branch of treatment to Africa, chemo-therapy, I will refer to later.

From what has been said, it is not surprising that British pharmacology should be so much behind that of other countries in the production of new curative remedies; practically all come from abroad; I may mention ephedrine for spasmodic asthma, liver extract for pernicious anæmia, insulin, the organic arsenicals, the dyes such as 205, the new anæsthetics local and general, hypnotics, and many others.

It has been often stated that the action of remedies may be best determined by experimenting with them on healthy men. This is not true; quinine is used to treat malaria, yet not one of the subjective symptoms induced in man has the remotest connection with its curative properties. The same is true of the use of the iodides in syphilis and salicylates in rheumatism. The experiments of Joig and his pupils in 1825 with camphor, digitalis and other drugs on healthy men added nothing of value to pharmacology. Subjective sensations are, it is true, produced, which are erroneously attributed to the drug which has been taken. The late Dr. Rivers and myself were nearly the dupes of such an experiment which I will give in full because it illustrates the imaginary sensations and effects produced by S. Hahnemann and his pupils, by Perkin with his retractors and by more modern physicians with their mystic apparatus.

Our experiments were made on healthy men under a regular regime as regarded sleep, exercise, and diet. The men were practised with the use of the ergograph during several weeks at the same hour daily, until

their output of work was constant. We found that the administration of a dose of caffeine dissolved in water one hour before the experiment greatly increased the output of work for that day. This was repeated on several occasions, always with the same result, and we naturally regarded the effect as due to the caffeine. This, however, was not the case: the effect was due to the ritual of taking a drug; the drug day assumed an enhanced importance in the mind of the operator and the mental effect sometimes referred to as suggestion was principally responsible. We had no difficulty in showing that water made bitter with a trace of quassia or other simple bitter had a similar effect.

Few, if any, experiments made on man without the most careful controls are of any real value. Properly controlled experiments have been made, however, with many substances. Precise experiments, for example, have been made both in Germany and America with bromides in epilepsy. In these experiments half the epileptics were given potassium chloride and the other half sodium bromide; after several weeks' use the bromide had decreased the number of attacks, whilst the chloride had no distinct action.

CHEMO-THERAPY.

At one time hopes ran high that the chemical structure of the molecule might indicate pharmacological action. During the last fifty years many laborious researches have been conducted with this object; to modify the molecule that it may conform to some required action. But the mystery remains as mighty as ever. It is most probable that subtle energy factors binding the molecule—factors not displayed in a formula—control the action; certain it is that drug action is not determined directly by chemical combination with body constituents, but rather by delicate physical processes such as those of adsorption, solution, and surface tension. Chemists have as yet not even determined the requirements of the molecule for the production of colour sensation. On the other hand, slight alteration of a molecule already complicated and with a known action has led to the production of many useful compounds, and not infrequently we may foresee the type of action which will occur under such special conditions. Considerations of this nature have led to the synthesis of the new local anæsthetics, antiseptics, antipyretics, diuretics, tropeines and other useful substances.

But chemistry has taken yet a further step in its assistance given to medicine in the development of that branch of science to which the name chemo-therapy has been given. Ehrlich noticed that colouring matters injected into the living organism had a selective affinity for certain cells, and he believed that it might be possible by making use of this property to select suitable substances which would destroy the causal agents of disease, parasites and microbes, and leave the tissues of the host uninfluenced.

Parasites causing disease in man may be crudely divided into worms, protozoa, and bacteria. Chemo-therapy, that is specific therapy of infectious disease, has had marked success in curing disease due to parasites in the first and second of these groups; these diseases are found mainly in the tropics. It has obtained much less success in the third group.

Diseases due to protozoa have an especial significance in Africa, and it is appropriate that in this meeting some reference should be made to that area of tropical Africa occupying more than a million square miles in which one form of these, namely, trypanosomes, produce their ravages.

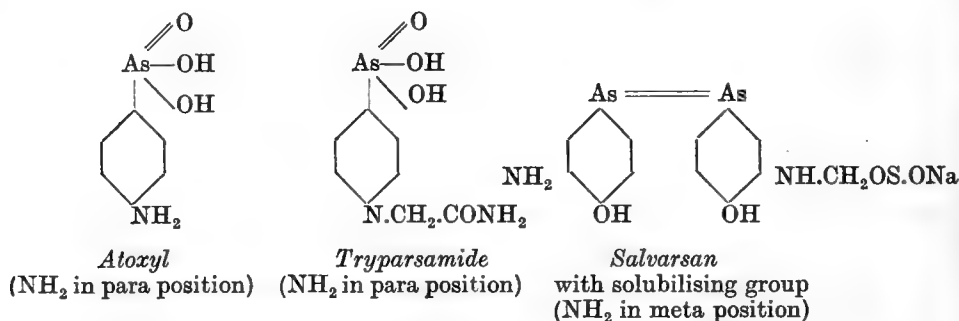
Disease of man produced by trypanosomes is confined to tropical Africa and some of the adjacent islands. But an enormous belt of country stretching from Rhodesia northward to the Bahr el Ghazal, and from the Cameroons westward to Tanganyika is inhabited to a greater or less degree by the infected tsetse fly. Two forms of trypanosomes are known to infect man, *T. Gambiense*, which is especially common in the neighbourhood of the two great lakes, Victoria and Tanganyika, and northward of these to the tributaries of the Nile. The other, *T. Rhodesiense*, is mainly found in the country surrounding Lake Nyasa, Portuguese East Africa, Nyasaland, and Rhodesia: this form is more rapidly fatal than *T. Gambiense*, and its treatment is less satisfactory. Epidemics may occur in different districts from time to time: thus in 1900 an epidemic occurred in the Belgian Congo in the neighbourhood of Kisantu, in which two-thirds of the population succumbed within ten years. It is probable that the population on the northern border of Lake Victoria Nyanza had existed for generations without trypanosomes (sleeping sickness), although *Glossina*, the carrier, was plentiful. It then happened that some migration of natives, possibly caravan porters from the Congo, introduced the trypanosome, and a terrible epidemic of *T. Rhodesiense* swept the country in 1898, spread round the Lake and killed about 300,000 natives. The natives and their cattle were removed in 1909 and the infested district was left to the fly. Dr. Duke points out that the *Glossina Palpalis* had hardly diminished in the succeeding eight years, and he regards wild game as a trypanosome reservoir; he showed in 1911 that the situtunga serves as a mammalian host for the trypanosome as well as man, in the same way as N'gana is carried by many species of game; in this way the fly retains the trypanosome which causes sleeping sickness. In Uganda, at any rate, lizards and crocodiles form the chief sources of food for *G. Palpalis*.

T. Gambiense is transferred by *Glossina Palpalis*, *T. Brucei* by *G. Morsitans* and *Pallidipes*, and *T. Rhodesiense* by *G. Morsitans*. Innumerable other instances might be given of its ravages in the whole of the Congo, Cameroons, and other parts of Africa. Besides the human form of the disease, another tsetse fly is responsible for the trypanosomes of domestic animals, including horses and cattle, *T. Brucei*, which produces the disease N'gana, so that in infected districts draft animals and dairy cattle cannot exist.

Trypanosomiasis is one of the most serious of all tropical diseases and affects both man and beast; it is a scourge which renders vast tracts of land practically uninhabitable, and which takes its death toll often in thousands and occasionally even in hundreds of thousands, and yet it is a disease which I believe should be curable if not preventable. The problem is one of wide interest and importance—scientific, humanitarian, and economic. The members of two groups of chemical substances excel all others in their curative value in trypanosomiasis and spirochætosis; these are the organic arsenical compounds and the dyes.

The specific action of organic arsenic compounds really begins with some observations of Thomas on the action of atoxyl on trypanosomes. Ehrlich had previously discarded this substance because it was without direct action on the protozoon, but later he observed, like Levaditi and Mesnil, that in infected animals it had a more pronounced action than that of any other substance up to then employed. Atoxyl was, however, soon discarded as a curative remedy because it caused permanent and complete blindness in some cases. Acetyl atoxyl, known as arsacetin, which was at one time widely used, had no better fortune, and several cases of permanent blindness resulted from its use. Ehrlich's experiments with Hata, in which innumerable arsenical compounds were employed, led him to select salvarsan as the best: in this substance the nitrogen and arsenic are in the meta position and not in the para as in atoxyl. This substance as a treatment of syphilis and other spirochætal infections stands as firmly to-day as it did ten years ago; it has one drawback, it does not influence the condition of the patient if the central nervous system is attacked. By introducing $\text{CH}_2\text{OS.ONa}$ in place of one of the hydrogens in the amino group a soluble compound is produced which has displaced the older salvarsan on account of its ease of administration; nevertheless this neo-salvarsan contains as much as 10 to 20 per cent. of unknown impurities. Other substances like tetra-methyl hexamino-arsino benzene (Arsalyte Giemsa) have been produced which are also very efficient in spirochætosis.

It is well known now that none of these compounds act directly on the parasite (Ehrlich, Levaditi, Mesnil, and others) like arsenious acid.



It was at one time thought that the action of these arsenicals depended on their solubility in lipid substances and their subsequent oxidation to arsenic in the ionic form: but after their administration to animals no trace of oxide is found in the body. About 115 mgrms. of atoxyl per kilo can be injected into mice, but only about 2 mgrs. per kilo of the corresponding oxide for the maximal sub-lethal dose. It is probable that the lipid soluble and inert atoxyl in the pentavalent form is converted into the trivalent form which destroys trypanosomes like arsenious acid. Fournneau from a great number of experiments with different organic arsenicals concludes that their varying constitution as regards the introduction of different side-chains in the ring, and the varying positions of these relatively to one another, is the factor which determines their

distribution in the organism, particularly as regards the central nervous system.

The most satisfactory arsenic compound yet discovered for the cure of trypanosomiasis is tryparsamide. It is less toxic than atoxyl and has a slightly higher therapeutic index; it has a most marked trypanosidal action in animals and has been used with some success in cases of sleeping sickness from *T. Gambiense*. One injection causes the disappearance of the parasite from the blood of man, and if the injections are repeated in courses, the cure may be complete. Like atoxyl it affects the eye: even the smaller therapeutic doses cause visual disturbance, and the risk of complete blindness is always present; perhaps as many as 30 per cent. of all patients treated with this drug suffer from some eye lesions. Tryparsamide is valuable also in certain forms of syphilis, particularly cerebral syphilis: approximately 40 per cent. of the cases of general paresis committed to the State Insane Hospitals in Wisconsin, U.S.A., were restored to sanity (Loevenhart). This action is probably indirect since there is no evidence to show that it is absorbed into the central nervous system more than other organic arsenicals.

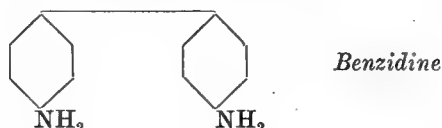
All these organic arsenical compounds must be injected in order to produce a satisfactory effect; but one compound, m. amino-p. hydroxyl phenyl arsenic acid, acts upon and destroys spirochætes when taken by the mouth (Levaditi); it is generally administered as its acetyl derivative which is known as stovarsol. Stovarsol has been largely used as a preventive to syphilis, but it is now known that it has a remarkable curative action in amœbic dysentery like emetine (Valenti), and that in cases of benign tertiary malaria it checks the attacks and prevents the return of the disease, at all events for many months.

It was at first thought that, as laboratory animals are so easily infected with trypanosomes, it should be an easy matter to determine which compounds were likely to be most valuable in the treatment of trypanosomiasis; unfortunately this is not the case, a drug may cure trypanosomiasis in one animal and not another and the crucial tests must always be made on man. Fournau's o-hydroxy p. acetyl amino-phenyl arsenic acid (270) acts much better on laboratory animals as a cure for trypanosomiasis than tryparsamide, but has not proved so satisfactory as tryparsamide in the Congo for the treatment of sleeping sickness. Since the crucial test with all these compounds must be made in Africa it is obvious that the expense and difficulty of continuing such researches is enormous.

Most of the antimony derivatives corresponding with the organic arsenicals have been prepared; for example, that corresponding with acetyl-atoxyl, also m. chloro-p-acetyl amino phenyl stibamate of soda (Heyden 471) have been extensively employed in Kala-azar and Bilhartzia. Speaking generally, they have a more powerful action than tartar emetic on such diseases as Bilhartzia, Kala-azar, and Filaria, and to some of them, like sodium antimony thioglycollate, the parasites do not become readily immune. Unfortunately, the organic compounds of antimony have a toxic action on the tissues and are very difficult to administer, so that antimony tartrate or stibamine urea ($\text{NH}_2\text{CO.NH.C}_6\text{H}_4\text{SbO}(\text{OH})_2$), a compound which has recently been prepared pure, are generally preferred.

DYES.

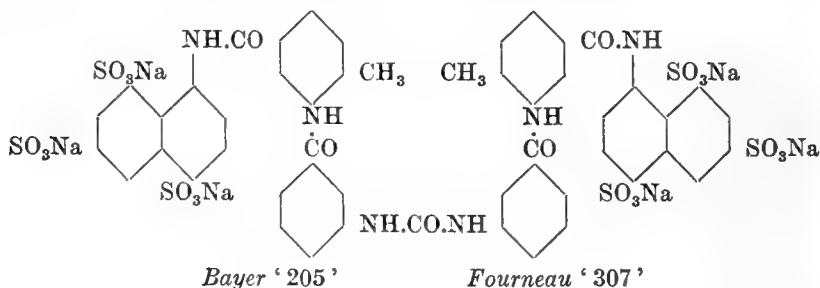
Many dye substances have been used in medicine : as they are readily adsorbed on to cell surfaces the concentration here is always high and the surface properties of such cells are often modified in consequence. One general principle which follows from this is that widely different dyes often possess properties in common, for example, that of antiseptic ; to-day I propose to refer only to one group, the benzidine dyes.



Trypan red and trypan blue belong to this group. Trypan blue was employed by my colleague, Prof. Nuttall, in piroplasma infections in animals, with results that most South Africans are well acquainted with. Afridol violet, a derivative of diamino diphenyl urea, and some allied dyes have also a powerful action on piroplasma.

How these substances act is not known, for like the organic arsenicals they do not kill the parasite in vitro. They have the property, however, of being adsorbed to the blepharoplast of the trypanosome ; this adsorption is associated with diminished virulence of the parasite in infected animals, and after successive inoculations through several animals the organ may disappear. This direct action of a drug on a tissue, causing ultimately the complete disappearance of that tissue, is so remarkable that it is worthy of notice, as it represents the first known action of the kind.

The most valuable member of the afridol-violet group so far produced was first made in the Bayer laboratory, but its composition was kept secret. It was, however, subsequently synthesised and its formula published by Fourneau, but only after long trials and infinite patience. The chemo-therapeutic index of this substance has the remarkable figure of 200 to 300 ; and as little as 1/32 mgrm. will sometimes cure mice infected with trypanosomes. Fourneau has made many allied substances and derivatives of '205,' he has modified the wings of the molecule by the addition of various side-chains, sometimes keeping the wings identical and sometimes changing them by joining two different complexes through the agency of phosgene. The number of such derivatives is obviously legion, and this makes it the more remarkable that he should have succeeded in synthesising '307,' which at the present time is superior as a therapeutic agent to all other dyes in trypanosomiasis.



This '307' has a remarkable action on trypanosomes in laboratory animals, being 300 times more effective than atoxyl. Its discovery has also opened a new era in therapeutics, since it represents the first chemical substance which when administered to man or animals in an infected trypanosome district gives a complete immunity to the disease for several months: it does not necessarily prevent trypanosome infection, but it prevents the effects of the disease. There is much in these experiments that suggests that we are on the fringe of a new pathology, and that our present crude methods of preparing anti-bodies in the future will be replaced by those of the organic and colloid chemist.

In man '205' has not done all that was expected of it; it invariably benefits those that show infection and enlargement of glands, that is during the early stages of the disease, and its value is also assured even when the nervous system is affected. If care is taken in the treatment and a series of injections given at not too frequent intervals to prevent the parasite acquiring a tolerance, and if the patient is kept under observation for a prolonged period of time, the happiest issue may be anticipated. '307' is much less valuable on n'gana in animals.

I have already referred to the disappointing results of research dealing with chemical constitution in its relation to pharmacological action, but it may be well to consider whether there is anything in common between the various substances noted and their effects on protozoa. It must be evident at once that with such widely different substances it cannot be the form of the molecule which is important so much as its side-chains or physical properties, although a large molecularweight appears to be an advantage. Many of the dyes, like flavine, fuchsin, and methyl violet, have two amino radicles in the para position, relative to the carbon atoms uniting the nuclei. The azo-dyes and the innumerable derivatives from them, which have been examined by Nicolle and Mesnil, present no common features with those of the triphenyl methane group. Amino groups appear to be an important factor, but it is the position of these in the rings, even more than the character of the radicle, which determines the effect. The study of the complex butterfly-like compounds of substituted naphthalenes, such as Fournau's '307,' instead of simplifying our conception of the relationship between constitution and action rather increases the difficulties. In such compounds slight changes like desulphonation or demethylation entirely alter the therapeutic effect. These few examples are sufficient to exemplify the fact that the synthesis of new molecules in the hope of conforming with some pre-determined action is as yet far removed from practical science.

BACTERIAL INFECTIONS.

Tuberculosis is another problem of vast importance in South Africa, not only on account of its prevalence amongst susceptible individuals in both the European and native population, but because of its association with certain industrial diseases.

Much the most important industrial disease in South Africa is the silicosis produced in the extraction of gold from the conglomerate, both the pebbles and the matrix consisting of quartz. The gravity of pneumoconiosis depends largely on superadded tuberculous infection to which the

workers have a predisposition, and in this respect crystalline silica is much more harmful than either amorphous silica or carbon. However it acts, whether by direct irritation, by its poisonous properties after solution, by colloidal action, or because it forms locally a nidus suitable for the growth of the tubercle bacillus, will be discussed at a later meeting.

The report of the Miners' Phthisis Medical Bureau, dealing with the years 1914-1926, shows that the incidence of silicosis is increasing. Of the average number of 178,000 natives employed on the scheduled mines during the year 1925-26, of whom 133,260 were employed underground, simple tuberculosis was found to be present in 566, simple silicosis in 231, and tuberculosis with silicosis in 446. The large majority of cases of compensatable disease among European miners are cases of simple silicosis; among native labourers the great majority are cases of tuberculosis, mostly without silicosis. As compared with European miners the incidence of simple silicosis among native labourers is low, which according to the report mentioned is mainly due to the migratory habits of the latter, as silicosis takes time to show evidence. It may also be noted that besides tuberculosis the mortality from Bright's disease is high in silicosis.

Workers employed in other dusty trades, such as the preparation of asbestos materials, also suffer from pulmonary disability, and Dr. Collis found that five deaths from phthisis had occurred in five years amongst a staff of less than forty workers employed in a factory where asbestos was woven; asbestos contains about 50 per cent. of silica. The dust associated with the process of carding, before its extraction was efficient, at one time in England produced a pneumoconiosis resembling that of silicosis.

It is well recognised that a patient suffering from tuberculosis who is placed under treatment, will, for a time at least, improve in health, no matter what drugs, vaccines or 'specialities' may be employed. The beneficial result is due, in this as in other disease, to efficient nursing, to the regulation of food, exercise and sleep, and to light and fresh air. If only this effect were clearly recognised the number of 'treatments' in vogue for this common disease might be diminished. The enthusiastic physician sometimes begins the new treatment as soon as the patient enters his wards, and he is apt to regard the benefits which may follow as due to the special treatment. General hygienic measures are of primary importance in treatment, and it is not until all the beneficial effects which are known to ensue from these have been exhausted that the physician has any right to ascribe an effect, beneficial or otherwise, to a special treatment.

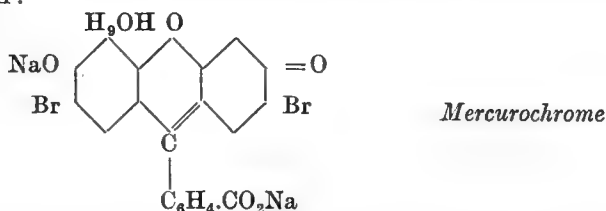
Drugs are employed in tuberculosis either with the object of attacking and preventing the growth of the tubercle bacillus or other organisms with which the disease may be associated, of neutralising poisonous toxins, or of removing or relieving symptoms. It is with the first group that I am now concerned. Two groups of organic compounds are especially remarkable for their chemo-therapeutic action on bacteria. The first group has the quinine complex; quinine is the methyl-ester of cupreine and it can be reduced by nascent hydrogen to form hydrocupreine. The following table shows the effect of two derivatives of hydrocupreine in arresting the growth of certain micro-organisms.

		<i>Ethyl hydrocupreine</i> (optoquin)		<i>Iso-octyl hydrocupreine</i> (vuzin)
Diphtheria bacillus ..	..	1 in 100,000	..	1 in 750,000
Pneumococcus ..	..	1 in 400,000	..	Negligible
Staphylococcus ..	..	1 in 500	..	1 in 16,000
Streptococcus ..	..	1 in 1,000	..	1 in 80,000

The action of optoquin on the pneumococcus and of vuzin on bacillus diphtheriæ is highly specific; the higher and lower homologues have a greatly diminished effect. Many substances destroy bacteria in the test tube, but these drugs act in the animal body as well as in the test tube, and enough can be given by medicinal doses to animals and men to render the blood of these animals bactericidal.

The second group of drugs which exert a marked action on bacteria are certain derivatives of acridine. Trypaflavin was used during the war for infected wounds: unlike most antiseptics it acts better in the presence of protein, but is not sufficiently selective or specific on micro-organisms in the presence of body tissues to be of any real value; it is easily absorbed and readily causes œdema. Rivanol is a more recent derivative of acridine. Morgenroth cured streptococcic infections by injections of rivanol under the skin. The injections to be efficient must be made soon after the infection and in the neighbourhood of the inoculated zone; rivanol will not cure a blood infection. Its discovery is, however, a great advance over any substance previously available in this group, and we can anticipate with some confidence in the near future the introduction of other derivatives which will destroy acute infective agents.

Two other chemical substances are worthy of consideration for the remarkable effects accredited to them in the treatment of microbial infections. Mercurochrome, a dyestuff, is a combination of mercury with dibromo-fluorescein:



After injection it is excreted by the urine and bile, yet neither the urine nor bile exhibits bactericidal properties. Nevertheless, clinical evidence shows that it exerts a curative effect, especially in the case of streptococcic and staphylococcic infections, and these effects have been repeated in animal experiments.

Hexyl Resorcinol is a representative of another group of substances. The introduction of an alkyl radical into resorcinol diminishes its toxicity to tissues, but increases its bactericidal properties.



Hexyl Resorcinol is represented by the formula $C_6H_3(OH)_2C_6H_{13}$. It has a phenol coefficient of 72 and it renders the urine in which it is excreted germicidal; many reports show that it effects remarkable cures in cystitis and pyelitis. Unlike mércurochrome the action of this substance, at least in the urine, may be direct on micro-organisms.

Attention has already been drawn to the important part played by surface tension in the destruction of micro-organisms by drugs: those substances in solution which depress surface tension are the more efficient germicides because they penetrate better; they are adsorbed by particles in suspension like bacteria, and they diffuse through the cell membrane inversely as the surface-tension is lowered. The alkyl derivatives of resorcinol all lower surface-tension, but the hexyl derivative most, and its bactericidal properties are largely dependent on this factor. In all this series of alkyl derivatives of resorcinol the bactericidal power was found to be directly inverse to the surface-tension. Frobisher found that using a wide range of dilutions the bactericidal efficiency could be precisely controlled by manipulating the surface-tension of these solutions by the addition of varying amounts of surface-tension depressants which are themselves devoid of bactericidal action. Thus Leonard has shown that 0.1 per cent. hexyl resorcinol with 30 per cent. of glycerine and water to 100 is one of the most powerful germicides known and possesses a surface-tension of 37 dynes per centimetre. Pathological organisms are destroyed by this fluid within 15 seconds.

The chemo-therapeutic substances which are known to act on bacteria are without value in tuberculosis. Thus flavine and its silver salts do not influence the tuberculous process in living animals, and the same is true of the quinine derivatives which have been prepared so far. The destruction of the tubercle bacillus presents two special difficulties: first in the fatty and protective envelope surrounding the bacillus, and second in the small blood supply to the tuberculous lesion.

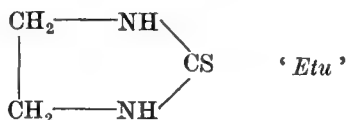
Success, however, has been claimed for several metallic compounds, and I shall confine my remarks to three of these. It is by no means clear that the results which have been obtained by administering gold salts to tuberculous patients or animals are superior to those given by copper salts which preceded them. 'Krysolgan' was introduced by Feldt; it prevents the growth of the tubercle bacillus in cultures in 1 part in 1,000,000. Nevertheless, animal experiments with this substance are not promising, though the clinical results published in Feldt's monograph in 1923 are certainly both helpful and inspiring.

Another 'gold' cure is that recently introduced by Moellgaard. It is a double thiosulphate of gold and sodium, $Au(S_2O_3)_2Na_3$, which, although a well-recognised substance, he calls 'sanocrysin.' Like its predecessors it retards growth of the tubercle bacillus in glycerinated bouillon in such strengths as 1 in 8,000,000, but how serum added to the cultures affects its action I have not discovered. Nevertheless, this is a very important point, since such chemo-therapeutic substances as exert an undoubted action on bacteria invariably act the better in the presence of the tissue fluids. Moellgaard assumes that his gold injections destroy the tubercle bacillus in vivo, and states that doses which are not poisonous to normal animals kill the tuberculous animal by producing a tuberculin

shock. This shock begins with an albuminuria and sometimes hæmaturia; it is followed by toxic myocarditis and pulmonary œdema. There is, however, no clear evidence to prove that the shock in tuberculous animals after an injection of sanocrysin is due to the destruction of tubercle bacilli and the setting free of endotoxins, which act as tuberculin acts on tuberculous animals.

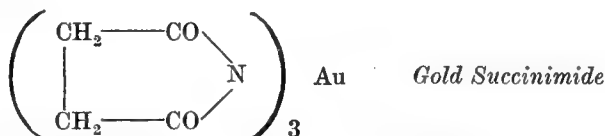
Another feature of importance in these experiments is that the cultures used were attenuated. The doses necessary to kill were enormous and many control animals failed to die or contract severe disease.

Hoyle and I have recently investigated two new types of gold compounds in tuberculosis. One of these is a complex aurous salt of ethylenethiocarbamide with the formula $(\text{Au}, 2\text{etu})\text{H}_2\text{O}$, where etu represents ethylenethiocarbamide.



This compound, prepared by G. T. Morgan, is stable, crystalline and colourless at ordinary temperatures. It is soluble in distilled water, forming a solution neutral to litmus and with a pH value of about 6.2. It was tested for therapeutic effects on both human and bovine types of infection. For the former, inoculations were made subcutaneously into guinea-pigs with 1-mgm. doses of a virulent human strain. All the animals, control and experimental groups, died within a few days of one another and all showed characteristic progressive lesions of similar extent.

It was found that treatment with the gold compound in bovine disease in rabbits prolonged life about 50 per cent. when compared with controls. We adopted the arbitrary standard that treated animals should survive at least two or three times longer than the average length of life of the controls before clinical trial should be proceeded with. In view of the wide variations in individual susceptibility, and the difficulty that this entails in drawing sound positive conclusions from a small series of animals, it is absolutely necessary to exercise the utmost caution before arousing clinical expectations.



The second compound tested by us was a complex gold derivative of succinimide, prepared by my colleague, Sir William Pope. This compound is non-ionised and the gold is associated in chemical combination in an internal organic ring. It is a white, crystalline, stable compound at ordinary temperatures, readily soluble in water to a neutral solution.

This substance was tested for therapeutic effect in experimental bovine infections in rabbits. In some animals this treatment was supplemented by injections of potassium iodide subcutaneously; in no case have any therapeutic benefits been observed. There has been no increase in the

lengths of life of the treated animals, and the type and extent of disease at post-mortem examination in treated and control animals has in every case up to the present been similar.

These compounds are interesting because the one delays death and the other is entirely without action. They may afford a hint as to the lines on which organic chemists should proceed, and perhaps show that gold in the ionic form is desirable.

THE INTERNAL SECRETIONS.

In the last twenty years much evidence has accumulated to show that the glands of internal secretion are responsible for the regulation of growth, of metabolism, and often for our appearance if not for our very character. Exaggeration or diminution in the secretion of one or other of the tissues may induce conditions so decided as to be obvious to everybody, though the effects produced by minor alterations in the co-ordination of the several secretions may not be so evident. Giants and dwarfs, unusual pigmentation and anæmia, disproportion in the growth of the skeleton, such as enlarged hands and face, bulging deer-like eyes or oriental eyes and beards in women are noticeable to everyone; excessive fatness or emaciation, a choleric or bucolic temperament cause no comment, yet may equally arise in the victim from a want of co-ordination in the internal secretion.

The general outlook and significance of drug therapy was led into new channels when it was revealed that the animal body through these glands elaborates its own drugs, stores them generally at the seat of formation, and doles them out to the tissues to meet the needs of the economy. Some of these drugs are of the nature of alkaloids comparable with those elaborated by plants. It is a remarkable fact that when Nature elaborates a drug in either a plant or an animal, that drug is invariably the ideal drug for producing the action for which it is characteristic. No drug relieves pain like morphine or produces local anæsthesia so well as cocaine; no drug paralyses the para-sympathetics so perfectly as atropine or the motor nerves so effectively as curarine; strychnine supersedes all other drugs in exaggerating spinal reflexes, and caffeine in its remarkable power of stimulating the psychical centres of the brain. Of the animal drugs, adrenaline has a superlative effect on the sympathetic system, pituitary on the uterus, and thyroxin on general metabolism.

The elaboration of the drugs in nature is on biological lines and the key always fits the lock: it seems as if Nature always says the last word on the particular type of drug she elaborates. Certainly organic chemists have up to now done little to improve on her products.

THE SUPRARENAL GLAND.

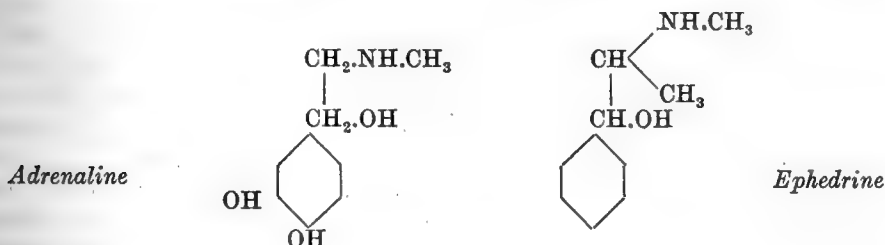
The suprarenal gland is composed of two distinct organs. The medulla elaborates an alkaloid named adrenaline, the action of which corresponds with stimulation of the entire sympathetic system. What exactly its functions may be in the animal economy is not certain; its output under

normal conditions is so limited that it can hardly affect the blood-pressure and it is not apparently essential for life. There can be little doubt, however, that in moments of excitement adrenaline is liberated in large amounts and that it is responsible for some of the expressions of the emotions. The action of adrenaline under such conditions is to raise the blood-pressure by constricting peripheral vessels, to dilate bronchioles, to erect the hair, to increase the blood-sugar, to immobilise the alimentary canal, and to facilitate the clotting of blood. Cannon has shown that cats respond to psychical stimulation, such as may be induced by the presence of a dog, after the entire thoracic sympathetic system has been removed; the interpretation must be that in these emotional conditions adrenaline is set free in relatively large amounts.

The expressions of the emotions, such as anger and terror, are to the animals an advantage: the easy breathing, the ready clotting of the blood, the increased circulation may all have their advantages in a fight. The ultimate cause of spasmodic asthma is constriction of the bronchiolar muscle; if during an asthmatic attack the patient is subjected to some sudden terror or other pronounced emotion the attack sometimes promptly ceases, in a manner exactly simulating the way in which a small injection of adrenaline will abort an attack.

In parts of West Africa the Calabar Bean, *Physostigma*, was sometimes used, in trial by ordeal, to determine the innocence or guilt of persons accused of witchcraft or other crimes. A normal person after drinking an infusion of this bean promptly vomits and gets rid of the poison. In states of emotion, which might well occur in a guilty person, the stomach is flaccid and immobile, vomiting does not occur and the poison is absorbed. The adrenaline takes some part in this inhibition of vomiting as it stops the movements of the stomach. The bean ordinarily induces violent contractions of the stomach which cause reflex vomiting.

Ephedrine is an alkaloid which is obtained from a Chinese plant, *Ephredra*, and which has been used by the Chinese as a medicine from time immemorial. It will be seen from the two formulæ that it is closely related to adrenaline and has an action very similar to it; but ephedrine acts when taken by the mouth, whilst adrenaline is so easily oxidised that it is destroyed when administered in this manner; adrenaline causes pulmonary congestion by dilatation of the coronaries: ephedrine has no such effect. These are only some of the differences between these two closely related alkaloids.



Ephedrine has proved of great value in the treatment of spasmodic asthma, since oral administration produces prolonged broncho-dilatation.

THE PARATHYROIDS.

Another striking result from experimental work in the field of internal secretion has recently been obtained in the case of the parathyroid glands. Many vague and unsatisfactory statements existed in the older literature as to the functions of these bodies: but now a potent extract of bovine parathyroid glands accurately standardised can be obtained, and precise knowledge of the part these glands play in the animal economy has become possible. Extracts when injected into a variety of animals raise the level of the blood-calcium; if the injection is made into an animal that has been previously parathyroid-ectomised, tetany and the usual fatal outcome are prevented. Repeated or very large doses in normal animals produce a condition with a definite clinical and biochemical picture—a condition of ‘hyper-calcaemia,’ in which the blood-calcium may rise to very high levels and in which a characteristic train of symptoms is found with terminal renal failure. Many secondary changes occur, of course, in the blood chemistry, but a closely similar if not identical syndrome is produced by the simultaneous injection of large amounts of CaCl_2 and NaH_2PO_4 .

All this work has shown beyond doubt that the parathyroid glands produce a substance which is responsible for controlling the level of blood-calcium, and that interference with this function by removal or disease of the glands can be overcome by treatment with the potent extracts now available. How this substance, manufactured by the glands, produces this effect has not been completely elucidated. Much evidence suggests that the rise in blood-calcium is independent of any change in absorption from the gut or in the rate of excretion: Greenwald in prolonged experiments on dogs, and Hunter and Aub in men, obtained indirect evidence to suggest that the rise in blood-calcium and consequent increased excretion after the injection of parathyroid hormone was due to mobilisation of the element from the bone reserves.

THE OVARY.

The gonads present the clearest evidence of the influence which a tissue may exert on metabolism. I will refer only to the ovary. Virchow is reported to have said that all the peculiarities of the body and mind of woman, all which in the true woman we admire and revere as womanly, are dependent on the ovary. Knauer showed that this organ was intimately connected with oestrus and that ovarian grafting could at least partly antagonise the effects of spaying. This ovarian action can be produced in both sexes. If a portion of an ovary is grafted into a castrated male animal the mammary glands and teats hypertrophy, the glands develop to the secretory stage and the animal comes to resemble a pregnant female: males so grafted become hyperfeminine in appearance. In the male the development of the mammary glands is uninterrupted, the Graafian follicles mature but do not rupture, and the ovary soon degenerates. In the engrafted female, development is slower and, unlike the male, shows a rhythm which is associated with the development of the Graafian follicle, and in the regressive phase with its rupture and the formation of the corpus luteum.

The ovary does not function till puberty and there is considerable evidence to show that this is brought about by some internal stimulus. A young ovary grafted into an adult male or female will begin its secretion sooner than its age warrants, whilst an adult ovary engrafted into a young animal will not function until the animal reaches maturity. This fact is of practical importance, since in cases of infantilism it is not necessarily the ovaries which are at fault and ovarian transplantation may not improve the patient.

The literature contains plenty of examples of the beneficial effect of ovarian transplantation, both in men and animals. For example, a bitch, aged 17 years, after an endoperitoneal transplantation showed rejuvenation, sexual activity, and gave birth to five normal puppies. Bell analyses 118 cases of ovarian grafting, and states that menstruation was possible in 107 cases of these, and occurred in 71. The ovary differs from other organs of internal secretion in that it functions in a cyclic manner, and it is obvious that extracts made from ovarian tissue may exert a different action according to the period of the cycle when they are made.

Numerous extracts have been prepared from the ovary which are reputed to exert one or other type of action.

'Oestrin' is the name given to one such substance: it can be made from many sources, both animal and vegetable, besides the ovary. Oestrin exerts a very definite action in lower animals, but its use in man is so variable and disappointing as to make it valueless in practical medicine. When it is injected subcutaneously into spayed rats and mice it produces typical oestrus with normal sex instincts, and when injected into immature animals it induces puberty; regular injections at fixed intervals will keep animals sterile.

Many experimental observations show that the corpus luteum is concerned with the rhythm of the oestrus cycle and with the prevention of ovulation. A persistent corpus luteum, both in the case of animals and women, produces sterility, a condition which is cured by its removal. The presence of fully formed corpora lutea appears to inhibit some ovarian secretion, and this condition obtains in animals for a time between the heat periods, but more particularly during pregnancy. In women there is plenty of pathological evidence to show that functional corpora lutea are not present during menstruation.

If the corpora lutea exert this controlling action on ovarian function, then their removal should release the normal ovarian function; such operations during pregnancy are invariably followed by abortion. On the other hand, injections of properly prepared corpus luteum prevent ovulation; this has been shown in the case of the hen, the rabbit, and the guinea-pig.

INTERSTITIAL HORMONE.

A third active substance distinct from oestrin and corpus luteum is elaborated from the ovary and was described by Marshall and myself. This substance is water-soluble and thermo-stabile, and can be prepared from the ovary at one stage of its cycle only, by maceration with warm saline followed by boiling and filtering. The injection of this substance into animals causes a secretion of pituitrin, and this in turn renders the

uterus supersensitive and highly responsive to other forms of stimulation.

The pituitary secretion passes either entirely or mainly into the cerebro-spinal fluid. Histological examination has shown that the gland is suspended in a bath of cerebro-spinal fluid and has an opening, at least in some animals, directly communicating with this fluid. Since the experiments of Marshall and myself this secretion of pituitary into the cerebro-spinal fluid has been confirmed many times, more particularly by Trendelenburg, Janassy and Horvath, Miura and Siegert. The reason some investigators have failed to find pituitrin in the cerebro-spinal fluid is because they have tapped the theca too low in the spinal axis. Pituitrin after excretion is rapidly absorbed and never reaches beyond the cervical cord. It has been suggested that the secretion of oxytoxic substance is not really pituitrin, but some other substance, and to this it can only be replied that it exerts every known chemical and physiological action of posterior lobe extracts. In my Dohme Lectures I gave the last piece of evidence in this respect by showing that it also exerts the melanophore dilator action on the frog, an effect which, so far as I know, is quite specific. Trendelenburg has also described this action.

The pituitary gland is intimately connected with the phenomenon of pregnancy; statistics show that the size and weight of the gland in men and nulliparæ are about the same; in primiparæ the weight has increased by about 50 per cent. and in multiparæ by about 90 per cent., though most of the increased weight is due to the anterior lobe.

The posterior pituitary substance has at least three actions of importance in medicine: it inhibits the secretion of urine, it has an antagonistic action to the insulin effect, and it sensitises and, in larger doses, contracts the plain muscle of the uterus. The last action is so profound that it overshadows all the other muscular effects, and pituitrin may be said to have a true specific action on uterine muscle in rendering it supersensitive to every form of extraneous stimulus.

Our experiments showed that at one stage only of the ovarian cycle was this hormone elaborated, namely, at the stage when the corpora lutea are degenerating. So long as the corpora are functioning they control the metabolism of the ovary, but when they degenerate control is lost and the ovary liberates the specific substance which excites the pituitary gland to secrete. This means that extracts of the ovary made between the heat periods or during pregnancy are without effect on the pituitary gland, but extracts made just before the heat period or just before parturition induce secretion of the gland. As the significant action of pituitary extract is to sensitise the uterus it is difficult, if not impossible, to avoid the conclusion that these two phenomena are closely associated.

It is well known that substances introduced into the cerebro-spinal fluid find their way almost immediately into the blood, and hence it might be expected that extracts made from the blood of pregnant rabbits obtained at the time of delivery would have a contractile influence on the uterus; this has been found to occur. Similarly blood obtained from pregnant women at the time of delivery contracts the guinea-pig's uterus to a considerably greater degree than normal blood. Mayer collected the cerebro-spinal fluid from women during Cæsarean section.

This fluid he injected subsequently into ten women with deficient labour pains. In eight of the women pains were induced, which in four were followed by the birth of the child. In another case an intradural injection was made, which was followed by labour pains within twenty-four hours. Mayer states that the cerebro-spinal fluid contains the active principle of the pituitary responsible for the production of uterine contraction. Siegert found that pituitrin, which is normally present in the cerebro-spinal fluid, diminished in the later months of gestation.

The interaction of bile salts and pituitary secretion is antagonistic on the uterus. Hofbauer shows that there is a steady increase in the bile salts in the blood of pregnant women as gestation proceeds. He thinks that this factor is responsible for the control of the pituitary secretion during pregnancy and that toward the end of labour the pituitrin action overshadows the bile-salt action so that labour occurs.

All these experiments consistently support the view that in the presence of fully formed corpora lutea the normal ovarian secretion is held in abeyance, and this is the condition for a short part of the time between the heat periods, but more particularly during pregnancy. At the close of pregnancy, when the corpora lutea are in an advanced stage of involution, the normal secretory activity recurs and the pituitary gland is excited to secrete more actively. When the threshold stimulus of the pituitrin on the uterus is reached the pains of labour set in and parturition results. The well-known phenomenon of the growing irritability of the uterus in the later stages of pregnancy, which is the typical effect of the pituitary action, is explained as being functionally correlated with the involution of the corpus luteum.

It is not suggested that the ovario-pituitary endocrine mechanism is the sole factor in producing labour pains. No doubt the foetus itself acts as a direct stimulus, and without the foetus the intense muscular contractions would not occur, but it is also clear that the onset of labour cannot easily be accounted for without postulating some further exciting cause apart from the foetus and the uterus.

In conclusion, no romance can be more remarkable than the fact that doctors, by using pituitary extract to stimulate the uterus in pregnancy, should have adopted the method which Nature herself employs and that physiological function is after all a pharmacological action.

CONCLUDING REMARKS.

Civilisation has been responsible for many new diseases. Our food-stuffs in great cities are often preserved and important constituents of fresh foods may be lacking. The science of dietetics has assumed an enhanced importance lately, which is partly due to the artificial preparation of many of our foods. Many experiments have been made in my laboratory to show that certain foods given in excess to animals fed on a synthetic diet, but containing an ample supply of the recognised vitamins, suffer from poisoning sometimes of the most profound and fatal kind. The same experiments made on animals living on an ordinary diet show that the excess of the 'poisonous' food is harmless. For example, certain preparations of irradiated ergosterol given to rats which are being

fed on a synthetic diet act as a poison, but if the rats are fed on bread and milk the effect of the ergosterol is negligible. In real life we do not live on a completely synthetic diet; nearly everyone takes some if not an abundance of fresh food, so the practical value of this type of experiment may be over-estimated, though it is of considerable academical interest.

Civilisation has brought bad sanitation in houses, and even our windows may be depriving us of fresh air and filtering out certain rays of light, bringing its attendant tuberculosis—for tuberculosis is a disease of houses. Science is now engaged in endeavouring to remedy the evil effects which it has produced.

Civilisation is associated with wealth, indoor life, luxury, and sometimes excessive mental exercise. These are conditions which lead to exaggerated nervous sensibility, and this is a much commoner feature in those engaged in a mental indoor life than in those engaged in an outdoor physical life. It is not difficult then to understand the excessive use of tobacco in some of these people, since one effect of tobacco—and perhaps its most beneficent effect—is to increase the threshold of sensation in those who are supersensitive. When this supersensitiveness reaches extreme limits these people are referred to as 'neurotic.' They are so highly reflex, so easily responsive to external impressions, that the associations set loose by any ordinary stimulus cause such a complexity of cerebration that the ordinary affairs of life become a burden; they are not phlegmatic and uninteresting, but are often possessed of quick perception, a rapid response, and other higher attributes of mind which go to make up high breeding and culture. They easily weary of the strain and anxiety involved in the fight for existence, and anything that gives relief from their cares and anxieties is seized with avidity. Now it is these higher faculties of mind which are most responsive to narcotic poisons, which influence these long before those concerned with movement and ordinary sensation—so that the supersensitive people under the influence of narcotics lose the exaggerated effect of their sensations, and become more like normal people; the everyday trifles and inconveniences of life are no longer exaggerated out of proportion to their significance, and life, instead of being oppressive and anxious, becomes pleasant and free from worry. Sometimes the very acuity of their intellect is their undoing. Perhaps in a few special instances persons possessed of such vivid sensations may benefit by a narcotic which limits these conflicting impulses by allowing a freer play of some of the higher mental faculties; certainly the records of De Quincey and Coleridge suggest such a possibility. Hence it is easy to understand the modern tendency in some highly civilised nations to indulge in narcotic drugs like morphine, heroine, and cocaine.

It is another curious fact that it is just these supersensitive people who drink the caffeine beverages, like tea and coffee, in excess. Since the seventeenth century the use of the caffeine beverages has slowly increased, whilst that of beer and allied drinks has slowly diminished. Beer, from its essential oils and alcohol, is a soothing beverage; it depresses the higher faculties of mind, it does not exaggerate their activity. Caffeine, on the other hand, relieves drowsiness and fatigue by direct stimulation

of the brain cells ; it facilitates sensory impressions and the association of ideas. In large dose the caffeine beverages induce restlessness and nervous excitability, and they may produce disturbed sleep, headache and confusion. Few people, no doubt, take caffeine to this extent, but most of us take from 2 to 5 grains of caffeine daily, and the effect of this continued as a daily ration throughout life is a factor the significance of which is unknown. We do know, however, that caffeine increases sensitiveness to ordinary physical as well as mental sensations.

England was once a drunken nation, and the larger towns contained such notices as, 'Here you may get drunk for a penny ; dead drunk with clean straw for twopence.' Before the revolution the consumption of beer alone in England and Wales was 90 gallons a head per annum ; now it is about a quarter of this. With this diminution of beer drinking is associated a truly enormous increase in tea and coffee drinking. To me it seems not unlikely that this substitution of tea for beer is not wholly unconnected with the tendency of highly civilised nations to become supersensitive and neurotic, for this is the groundwork upon which drug addiction is built.

I have endeavoured to show that all precise knowledge in therapeutics is based upon controlled experiments on animals or man, and that the elucidation of the action of medicaments by the methods and data of experimental physiology is one of the most important steps taken to place medicine on a scientific basis. How important this is may be gauged from the fact that all fundamental advances in treatment in the last thirty years have originated directly or indirectly from experiments on animals.

There can be no doubt then that the future of therapeutics, and therefore of medicine as a whole, is intimately connected with physiology ; there can be no doubt that advance in the practice of medicine is dependent on those trained in the methods and fundamental truths of physiology, who devote themselves in the ward and biological laboratory to investigating how best to prevent or cure disease and so relieve suffering.

Britain for fifty years has every reason to be proud of her progress and achievements in physiology ; it is acknowledged that she can show records second to none and that her savants have included some of the world's greatest investigators. It remains for us to hope that in the future she may attain equal success in the associated sciences directly concerned with the relief of suffering and cure of disease.

SECTION J.—PSYCHOLOGY.

EXPERIMENTAL METHOD IN PSYCHOLOGY.

ADDRESS BY

F. C. BARTLETT,

PRESIDENT OF THE SECTION.

THE position which Psychology occupies to-day in relation to the other biological sciences, both theoretical and applied, is due directly to its adoption of experimental method. Yet if the psychologist is asked to point out any single unshakable discovery of first-rate psychological importance, based directly and wholly upon experiment, his attempts to answer the question are always regarded as unsatisfactory. Moreover, it is still common to find the most skilled and notable psychologists beginning their careers with an enthusiastic and active belief in experimental method and, as they develop, receding farther and farther from the laboratory and becoming more and more attracted by the claims of systematic general theory. Two reasons are assigned by everybody for these facts. Each is valid in itself; neither is helpful nor reassuring. They are, first, that experimental psychology is a recent growth, and second, that all psychological problems are discouragingly complex. It would be a bold thing to maintain that any method used in scientific investigation is fruitful in direct proportion to its age, while the fact that all psychological problems are complex is no justification for attacking them by theoretical methods which are of all ways the most likely to lead to over-simplification. It therefore seems worth while to attempt a survey of the use to which experiment has been put in psychology, in order to show what experiment has done, is doing, and what there is reasonable ground for believing that it yet may do for the advancement of psychological study. Such a survey may help to explain the curious fact that the very method which, more than anything else, has raised psychology to something like equal status with related sciences is still regarded with suspicion, both within and without the borders of the subject.

As everybody knows, the earliest experimentalists in psychology were physicists and physiologists, most of them with a strong bent towards philosophy in their outlook. They set up a standard which in various ways has cramped and confined experimental psychology ever since. When a physicist approaches a problem in which he has to state how a stimulus affects any kind of response, he is bound to lay the burden of explanation upon the stimulus. If this can be simplified, controlled, varied determinatively, resulting differences of response can be observed and explained. The stimulus also tends to be treated as outside the response itself. When the physiologist approaches the same type of problem, his emphasis is equally bound to be mainly upon the response side of the

relationship. This he perfectly legitimately isolates as far as possible, trying to state its characteristics in terms of the functions of the mechanism immediately concerned.

These are precisely the type of problem that the psychologist has most often attempted to carry over into his own field. Let us consider one point which grew out of the early experimental work on psychophysical methods. Fechner believed that all the content of experience, from the relatively simple sensation to the most complex reasoning content, was definitely measurable. Mainly as a result of his own observations, but aided also by the earlier work of Weber, he thought he could demonstrate this experimentally by showing that stimulus intensities and sensation intensities are related by a definite principle, the value of the unit sensation varying with the modality of stimulation. In order to establish the zero point for a sensation of given mode, and also the series of just noticeable differences piled up from this point by increase of the stimulus, he carried out a wonderful and patient series of experiments. He employed and somewhat improved Weber's method of 'limits'; he developed the method of 'mean error,' but he relied mainly upon the method, already proposed by Vierordt, of 'right and wrong' cases. Fundamentally, this method consisted in the presentation to an observer of a series of stimulus variables, each variable being presented a number of times over together with some standard magnitude, the order of presentation of the variables being haphazard. Thus for each stimulus variable a number of judgments were obtained upon its equality with or difference from the standard. As might have been expected, the observer was often doubtful and said so. Now, argued Fechner, if these doubtful judgments were resolved by an ideal observer, they would in the long run be equally divided on both sides of the alternatives which confront him every time he judges under these experimental conditions. Consequently, in determining the stimulus value which gave a sensation difference threshold, he adopted the plan of dividing the doubtful cases equally between 'right' and 'wrong' cases.

This procedure was speedily and acutely criticised by G. E. Müller. Müller pointed out, among other things, that the judgment in these cases is not simply a function of the stimulus on the one hand and of the sensitivity of the observer on the other hand. It is determined also by the *precision* of the observer, and this will affect the actual significance of the doubtful cases. But he did not go all the way with this notion; he thought that statistical manipulation could give him a measure, both of precision and of sensitivity.

Thus grew up a controversy which has proceeded voluminously ever since, though at the moment it seems nearly to have worn itself out. Broadly, four plans for dealing with these 'doubtful' judgments have been proposed and followed:

- (a) to divide them equally between 'right' and 'wrong' cases;
- (b) to ignore them;
- (c) definitely to instruct the observer to 'guess' when he is uncertain and then, if doubt still persists, to lump all cases together with 'guesses of greater' and 'guesses of less' as constituting an area within which stimulus variations have no corresponding sensation differences;

(d) to prohibit the observer from being doubtful.

Now all these devices ignore the very points which are psychologically the most interesting and important. First they tend to treat each judgment in the series as equally and independently significant, the function of the immediate stimulus. This is certainly wrong. For example, Wundt demonstrated long ago that a given judgment may express, not the immediate effect of its stimulus, but the cumulative result of a series of preceding stimuli and situations no one of which at once issues in a characteristic overt response. Again and again the status of a pronouncement in a series has been shown to depend on its order of presentation within that series. Secondly, no judgment of this type is the expression of a simple stimulus-response situation, but of a stimulus-attitude-response situation. To demand guesses and to prohibit doubt both alike determine an *attitude* of observation which spreads over the whole experimental situation, affecting judgments which are assigned certainty just as much as the others. During a few years preceding the war a number of extremely interesting experiments were carried out, particularly by Dr. Fernberger, upon the effect of 'attitude' in determining judgments obtained by psychophysical methods. For some reason these have never been adequately followed up, but they represent what I take to be a genuine problem of the experimentalist in psychology. In this case the question is: How are the judgments obtained in the various psychophysical methods determined? It is not enough to correlate immediate stimulus variations with immediate characters of response, or simply to describe the immediate response mechanism that is brought into play. When an observer enters into an experimental situation he brings with him propensities, tendencies, preformed organised systematic modes of response, the preformed cumulative organised effect of a mass of past discriminations. The stimulus, the situation that is presented, hits off some of these. They appear in him as an 'attitude,' and it is under the active control of this that he makes his responses. Only when we know more about how this is set up and about its precise effect upon the responses made, can we safely give to the latter the necessary weighting which makes their statistical treatment genuinely significant. I think that the psychophysical methods, studied from this point of view, will yet yield some enormously important results.

If the physicist in his approach to the stimulus-reaction type of problem tends to treat the stimulus regarded objectively as the main point of interest, the physiological method of approach is equally bound to concentrate its attack upon the immediate functional mechanism. It is of course foolish to argue, as is often done, that the physiologist is absolutely confined to a study of local response mechanisms, treating it as a matter of indifference whether they are in or out of their wider organic setting. But he does rightly lay the chief emphasis upon these, and for obvious and just reasons shrinks from speculation about central processes until he knows as much as can be learned about the peripheral functions and their mode of operation. From the earliest days up to the present a great part, perhaps the greatest part, of experimental psychology has been concerned with special sense reactions. Yet the psychologist has never staked out clearly any mode of investigation or characteristic problems which are specially his own in this

field. In this he has again been over-influenced by the great founders of his science. Consider the work of Helmholtz and of Hering on visual reactions. The former, with his very predominantly physical outlook, laid the burden of explanation always upon what the stimulus and variations of the stimulus can do. Only when he got into tremendous difficulties, as with simultaneous contrast, did he invoke processes, not directly visual, seated in the observer himself; and then, at once, his explanations became confused and unconvincing. Hering, being far more dominantly physiological, turned to a study of the immediately functioning mechanism. He, however, seemed to set the stage for much so-called psychological interpretation in later days, by elaborating a sort of speculative physiology in his theory of anabolic process within a local sense organ. When a psychologist takes up a problem of special sense reaction, his whole training and outlook force him to lay due weight upon the wide variability of such response when it takes place in its normal organic setting. If he has his eye upon the physiological mechanisms this variability constantly forces him back beyond the immediate peripheral functions to more central processes. Then, as again and again in the history of the subject, he is tempted to draw fanciful diagrams of the brain, laid out neatly into all sorts of areas of function; or, as is perhaps more common nowadays, he relapses into wholly speculative physics and physiology of the central nervous system. This is only trying wildly to do what the real physicist and physiologist are most chary of attempting, except as a kind of game, and it is no wonder that many of the more scientific psychologists are somewhat discouraged, while other people find it difficult to take the psychologist seriously.

Yet it is not the psychologist's view of the problem, but his handling of it, that has been faulty. Suppose we are investigating some specific sensory threshold. The response of our observer will be determined by a number of groups of factors. There are the physical characters of the stimulus: its intensity defined physically, its duration, often its medium of conduction to the sense organ concerned, relevant facts of its physical and chemical structure. There is the absolute sensitivity of the local responding physiological system, though this can never be absolutely measured short of cutting it out of its organic setting, which is just what the psychologist must not do, though the physiologist certainly may. There is the order of presentation of the stimulus in its series, which raises problems already touched upon in connexion with the psychophysical methods; and the correlated physiological questions of the state of adaptation at the moment of the sensory system. Operating over and above and through all of these are the tendencies, attitudes, moods, intellectual and emotional habits of the observer, the states variously characterised as states of confidence, hesitation, doubt, timidity, assertiveness, certainty. An image, flashing out suddenly at a given point, may change the whole character of a response and of succeeding responses. So may the verbalisation or formulation of a judgment. These so-called higher mental processes are precisely the psychologist's main concern. They can be experimentally set up and controlled to a large extent, while the other factors are kept relatively constant. It is our business to show how they are set up, and how they then powerfully determine reactions within the

special sense field, even in the simplest cases of such reaction. It is of no use simply to say that there *are* these determinants, and then to take refuge in a fruitless hypothetical physiology of the central nervous system. Perhaps the time may come when the bulk of sense psychology will be swallowed up in physiology, but that time has not come yet, and if we act as if it has we gain little but deserved suspicion from other scientists.

Already there are a few experimental studies of special sense problems from this point of view. They are less frequent and less thorough than they should be, and this is because the psychologist has generally been content to follow his more physically and physiologically minded predecessors, instead of envisaging the problems of sensory reaction for himself. When the psychologist studies a special sense response it is his business to try to show how that response, carried out in its normal organic setting, is being determined directly by facts other than those of the immediate sensory mechanisms. Cues other than those of the special sensory stimulus are operating through response systems of a higher, or more complex, order than those of the directly excited sense. For these response systems at present psychological names have to be used, and we have to show how they come into play and what they do.

It should therefore be particularly interesting to turn to the experimental attack upon the higher mental processes. I propose to take as typical the study of the responses called 'remembering' and 'recognising.'

The experimental investigation of memory is dominated by the work of one man who is commonly supposed to have been a great benefactor of experimental psychology, but who, in spite of his impressive work, seems to me to be the errant leader of a very sheep-like flock. In 1885 Hermann Ebbinghaus published his new programme for experiments on memory processes. Already, since 1879, he had been studying his own modes of recall by methods which were at that time novel. The publication of his results settled the direction of flow of the main stream of experiments on memory from that day to this. As everybody now knows, his great innovation was the use of nonsense syllables for memorising. He claimed for these four great advantages over any other type of material: they are simple; they are homogeneous; they can be indefinitely combined, but in all combinations the material remains essentially on the same level; they 'admit of quantitative variation which is adequate and certain.'

It is fairly easy to show that not one of these four claims is in fact sound, but for the present a single fundamental consideration is enough. It is always urged that nonsense syllables are the best material to use because they are 'simple.' That appears to mean something like this:

Suppose we are investigating normal taste and smell reactions. We know that generally these two are inextricably combined, so that much that we call taste is really smell. However, if we are interested in finding out how the end organs of taste react, we can experimentally cut off all olfactory reactions and see what happens. We then learn something true and important about how the end organs of taste behave when they are subjected to certain specific conditions. It is more than hazardous to assume forthwith that they behave in precisely that manner when the olfactory sense is alive and working. But there is no doubt a sense in

which we can say that the taste reactions thus experimentally studied are 'simpler' than those of normal everyday life. Now take the analogous case of remembering. A part of the total process is obviously the initial learning. If we use ordinary combinations of meaningful words or forms there may be a mass of associations, in some respects peculiar to each subject who submits to experiment, set up during this initial period of observation. By the use of nonsense syllables we cut off all, or most, of these thronging associations, just as in the other cases we cut off the olfactory sensations, and so we find out what pure and simple remembering can do.

The argument is feeble. We do not isolate the taste experiences by simplifying the stimulus, but by cutting off, through extirpation or temporary paralysis, those other reactions with which they are normally integrated. We can operate on the olfactory nerves in this way if we desire, but there are no specific memory nerve endings or nerve centres, or if there are we do not know them. Moreover, even if we could do this, the experimental psychologist would be untrue to his pretensions if he were satisfied with this alone. He pretends to deal with the intact organism. Suppose we do simplify enormously our stimuli, or our experimental situations and then confront our intact subject with these. All that happens is that he is faced by such an odd and unusual state of affairs that he is forced to mobilise all his resources and make up some novel reaction *ad hoc*. This is, of course, exactly what happened when the nonsense material was used. The early experimenters, being in other ways exceedingly good psychologists, saw this at once. Their way out was curious. They proposed that every subject must have long-continued practice with nonsense syllables before any of his results should be allowed to count. That is to say, having taken immense precautions to simplify experimental material and methods, we must then take equally great precautions to simplify, by rendering familiar, the highly artificial and complex response which we have thereby set up. The way in which this sort of method has run rampant over the whole of the laboratory psychology of the higher mental processes is distressing to anybody who wishes to adopt an experimental approach to this field of research. It is, perhaps, hardly an exaggeration to say that nine-tenths of conventional laboratory psychology—outside of experiments on the special senses—consists largely in showing how habits of response may be set up towards odd and out-of-the-way situations, and makes little contribution of moment towards the solution of any other problem.

This is the old difficulty in a new form, the exaggerated respect for the stimulus or the situation. The psychologist is studying the complex responses of a highly developed organism and how they are determined. They have been called forth to meet the claims of a very unstable and varying objective environment. They are no doubt in many ways more stable than that environment. But if the environment is violently simplified it is mere superstition to trust that they also get simplified in a corresponding manner. They become different, but are just as likely to become yet more highly complex. Stability of determination, not simplicity of structure in objective determining factors, is what we need to make our experiments convincing. Stability of determination is compatible with

complexity, and even with considerable variation of objective determinants. Somehow an experimental method has to be developed which recognises this fact.

I turn for a moment to experimental work on 'recognition' merely to bring out one further point of method. Since very early days an enormous amount of work has been done on this topic. It has issued in five or six different theories no one of which can claim finality. The diversity of this result is due to different causes, but one is perhaps particularly important. There is a strong tendency, when any complex response like recognition is being studied, to attempt to draw a ring round it and to seek its explanation within these imposed limits. Thus the explanation of recognition is sought in something that happens at the moment of recognition. This is surely wrong. An object or event may be recognised or not largely on a basis of how it was reacted to in the prior perception. A sound, for example, may be heard: it will not be recognised unless it is so listened to that it possesses qualities, characteristics, a setting and a significance. To the persistent study of a complex mental response as if its psychological explanation must be found inside an imaginary circle that encloses it, much of the disrepute into which experimental psychology tends to fall may be traced. It is perhaps the last and subtlest form of the outworn 'faculty' psychology.

I said at the beginning that the early experimentalists in psychology were physicists and physiologists with a strong bent towards philosophy. If in the history of the subject experimental psychologists have shown themselves too submissive to physical and physiological methods, it is even more true that they have often pursued philosophical ideals. This pursuit is in full cry still. A very brief consideration of current movements which originate in the laboratory will illustrate this point.

There is probably no contemporary movement in psychology which has more profoundly influenced psychological thought in English-speaking countries than the so-called *Gestalt psychologie*. I have, as every experimental psychologist must have, a very great admiration for the brilliant work of Wertheimer, Köhler and Koffka. It has shed much new light on old problems, as well as a good deal of old light on new problems. It starts specifically from experiments upon visual perception and its primary method is that of phenomenological description. When we are presented with a perceptual situation what is it that we experience? The answer is inevitable and is one which, from this point of view, has, I think, always been given. We cannot describe our experience in this sort of situation as a mosaic of tiny bits each corresponding with its isolable part of the stimulus or situation. The blue sky which is seen is not, as Köhler says, made up of an infinite number of blue sensation units, but is seen as a continuous blue expanse. The moving dots and lines, in Wertheimer's experiments, are seen, not as stationary points in temporal relations, but as a unitary and indivisible movement. Sometimes the experiments are more behaviouristic, but still it is the attitude of phenomenological description that determines their interpretation. The animal that has been trained to react positively to *a* and negatively to *b* at once reacts positively to *b* if *a* is removed and *c* is introduced bearing that relation to *b* which *b* had to *a*. This must be because the initial reaction was not to *a*, or to *b*,

and not to *a* and *b* and a relation between *a* and *b*, but to a total indivisible situation only to be described as *a-b-in-relation*. Again, an animal is set a complex problem and typically achieves the solution suddenly; for what we call the 'correct' solution is a reaction to the total situation as built, or figured, or formed.

Thus a fundamental psychological question tends to be: 'What is the nature and what are the characteristics of these indefeasible forms or patterns which stand over against all our reactions, compelling them to be as they are?' In our answer we can easily slip into the persistent error of over-emphasis of the objective side of the situation-response problem. I do not say they do this, but in his doctrines of physical *Gestalten* Köhler comes very near it. Or again, looking to the response side, we may try to build up inside the responding mechanism a complex system, somehow corresponding to the integrated phenomenal situation. Then, as in Köhler's theories of ionic concentration within the central nervous system, we are almost sure to slip into sheer speculative physiology. Finally, the phenomenological attitude seems bound to issue in a comprehensive theory about the nature of the world as we know it, rather than in a scientific study of the determination of human response. It is the latter alone which is truly amenable to experimental treatment.

There is another contemporary movement, also originating in Germany, much less widely influential in other countries at the moment, but likely to attract more and more attention. This springs from the work of Professor E. R. Jaensch. It also has a definite experimental basis. Jaensch experimentally discovered a type of imagery which seemed to lie somewhere between the after-sensation on the one hand and the genuine memory image on the other. I cannot attempt to describe his extremely keen investigation of this *eidetic* imagery, as he called it. At the moment the main point is that he considered it demonstrable that a proneness to eidetic imagery is correlated with a number of other reaction tendencies. He elaborated a theory of the two-fold division of all human subjects into integrate and disintegrate types. The integrate is the artistic, synthetic type, taking everything as a whole and having an inevitable accompaniment of persistent marked temperamental qualities and tendencies. The disintegrate is the scientific, analytic type, tending to split up presented situations and to deal with them piecemeal, and he also has his invariable, persistent, accompanying temperamental character. Of course the integrate and the disintegrate in their most marked forms are the extremes of a very wide range and pass the one into the other by very small shades of difference; but there remain these two predominant types, by a study and understanding of which all the problems of human reaction, in every field whatsoever, are to be finally explained.

Now this view does certainly seem to be biological in bent, and it is being explored throughout by experimental study. Moreover, it strives, and, I think, successfully, to avoid that artificiality which, as we have seen, hangs over conventional laboratory methods for the investigation of the higher modes of human response. It rightly treats our problems as problems of reaction tendencies, of their determination and their grouping. But it does seem to be rather in a hurry with its sweeping generalisations. Here are some extremely interesting observations on imagery. Why

should we hasten to fashion from them a key to all the most difficult problems of our science? It is what the psychologist seems everywhere prone to do. A departmental investigation is made to carry the weight of a comprehensive system. This, it seems to me, is the philosophical bias at work.

In contemporary English psychology there is only one complete and world-explaining system of this sort, and that is the system which has been developed by the keen and penetrating work of Professor C. Spearman. Here again we are invited to begin with experiment, not merely upon perceptual processes, not merely upon imagery, not merely upon more complex intellectual responses still, but upon any psychological problem whatever. Wherever we begin we shall speedily find illustrated the working of the few immutable laws upon which all mental structure, and it may be the very Universe itself, are built. They stand indeed at the portals of our science. Know them and everything is plain; ignore them and all is confused. They are conceived, not as tendencies serving the ends of biological adaptation, but after the fashion of physical principles of universal scope describing the inevitable structure and frame of mental life.

That Professor Spearman has done more for the development of several fields of psychological research than any other living Englishman cannot be disputed. His contributions to the development of psychological statistics, and his work in the field of the investigation of intelligence must give him a permanent place in the history of the subject. Yet the notion of experiment mainly as a tool for laying bare and illustrating the operation of a few basic and fixed laws must seem to the biologically minded investigator very unsatisfying. Having found a scheme which seems to set the results of certain experimental investigations in order, why should we, with all the wealth and variability of human response as our subject, try to fit the same scheme in everywhere? Surely to do this either our scheme must be so broad that its explanatory value in relation to particular concrete problems is bound to be very remote, or else it must be ruthless in its dealings with fact. In writing some years ago of his 'theory of two factors,' Professor Spearman said: 'It would seem as if psychologists have now got definitely to accept the Theory of Two Factors; it becomes a Bed of Procrustes into which all our doctrines must somehow be made to fit, even though the so doing may at times involve a not unpainful surgical operation upon them.' I admire the courage that prompts such a statement, but I find it difficult to square this attitude with that scrupulous regard for the immediate facts which must mark the experimental biologist.

No survey, however scrappy, of contemporary movements in experimental psychology can be satisfactory without some reference to Behaviourism. Of all the movements this is the one which is most thoroughly experimental, alike in its methods and in its formation of problems. It has laid firm hold on the point of view that experimental psychology is an investigation of the conditions determining high level biological reactions in animal and man. It is so round in its denunciation of philosophy that its excessive readiness to systematise its own principles of explanation is amusing. We can see this readiness in the haste with which

it has exalted the principle of 'conditioned reflex' into an all-embracing explanation, though many of the problems of human response concern the emergence of new effector functions and conditioned reflex has nothing to do with this; and though conditioning at the human level is excessively speedier and often far more stable than anything that has ever been experimentally observed. We can see it, also, in the Behaviourist's dogmatic assertion that the development of consciousness within any type of biological response never makes any difference in subsequent response. Such dogmatism is only another instance of the experimental psychologist's fatal proneness to run beyond his data. It is explicable in the light of a study of the origins of Behaviourism, for it was by the adoption of Behaviouristic methods alone that the investigation of animal response below the human passed from the anecdotal and analogical stage and became genuinely a part of biological science. But to push the principles involved into the whole of human psychology is just as bad as to carry out some departmental investigation into perceiving, or imaging, or thinking, or some sensorial function, and then to use the results forthwith as a master-key to all the problems of human determination.

Some of the reasons why experimental psychology has often attracted unfavourable criticism and failed to hold its students should now be clear. In work on the special senses it has frequently attempted to deal with problems that the physicist or the physiologist with their specialised training could solve more satisfactorily. In dealing with the higher mental processes it has been over-impressed with the necessity of standardising objective situations and has constantly proceeded as if the simplification of a stimulus were equivalent to the isolation of a response. Persistently it has shown unnecessary readiness to build upon specialised investigations wide systems which pretend a finality and universality that they do not possess. I believe the time has now come for pushing these criticisms vigorously and for attempting to meet them in practice. It could hardly have come much earlier. After all, whatever the limitations of his outlook, it may fairly be claimed that the experimental psychologist has done more than anybody else to keep alive the interest in special sense problems. As for the work upon relatively more complex processes a new and struggling science was almost bound to imitate methods already fully established in other fields and to exploit them as far as they would go.

By its shortcomings and failures, as well as through its successes, experimental psychology has been attaining the rank and outlook of a biological science. I will conclude this survey by saying as definitely as I can what I take this to mean.

Experimentalists everywhere are directly concerned with a study of the conditions under which the observable results that interest them can be shown to occur. In psychology the experimentalist is attempting to find out the conditions of the various reactions or modes of conduct that make up the lives of animals and human beings. At the human level most of these reactions appear to be accompanied and in part determined by some form of *content*: by sensations, images, judgments, trains of reasoning. Sometimes the psychological experimenter prefers to put his problems directly in terms of these, of how they occur and how, when they have occurred, they may, as conditions, influence other forms

or instances of content. Whether he deals with these questions or not there is one thing that is always held to distinguish his point of view from that of related scientists. He is primarily interested in the intact organism or the intact mental life. For the most part he cannot cut out partial responses, or special forms of content, and consider how they are conditioned in the absence of all the rest. If he could do this it would be foreign to his essential problem to make the attempt. He may, indeed, gain help from a study of instances in which certain types of response have been lost, leaving still a very complex organism, or mental life, to effect a readjustment of what is left. This, however, is clearly a very different matter from cutting out the partial response and studying that by itself.

The tendency to try to treat partial or specific forms or response each as much as possible by itself has, as I have indicated, persisted from pre-experimental days, and has done much to render experiments in psychology often trivial, uninteresting and highly artificial. The organism in which the psychologist is interested does not normally react with one sensory modality only, or with emotion untinged by information, or with impulsive activity free from interference by non-impulsive factors. All this might be unimportant, if by experiment the psychologist could force his subjects to adopt such simple modes of reaction. The psychologist would indeed be barred from making that direct passage from the laboratory to the world at large which he is very fond of making, but that would not be an unmixed evil. The situation is, however, more difficult than this. The subject of a psychological experiment always retains the possibility of making more reactions than the one that is being specifically studied. No matter how honest and painstaking both experimenter and subject may be, these 'other' reactions will play their parts in any results obtained. To try to shut up a subject to a purely visual or a purely auditory reaction, to pure perceiving, pure remembering, pure imagining and the like is, in fact, only to force him to utilise indirect cues so different from those which he constantly employs under normal conditions as, in many cases, to make his total reaction a genuinely novel one. The reaction has become artificial, that is, not merely because the range of its conditions is restricted, but because, with as wide a range of conditions imperfectly under control as ever, many of these are specific to this special experimental situation. The perfecting of objective control does not reduce the subject to a single sense, or a single cognitive or emotional process, but, leaving him as complex a reactive agent as ever, forces him to make up on the spot a type of total reaction fitted to this special environment.

Holding all this firmly in mind, what conclusions can we draw? First, it follows that the experimental psychologist must claim that for the present, and perhaps for always, he is as much clinician as experimenter. He has not merely to arrange conditions and record results. There seems to be a notion abroad that there is so much uncharted ground in psychology that an investigator can do anything he pleases, and so long as he observes everything possible, his results are bound to be significant. This is utterly false. His observation is definitely that of a man with a problem, and generally also with a personality, in view; and it is by consequence almost glaringly selective. He is not alone among experimenters in this respect. From a reading of the theory of the matter one might be

tempted to suppose that the best experimenter, once the experiment is arranged, would be merely a rather complicated and delicate recording and calculating device. Those who have a reputation for brilliant experimental work in any field singularly fail to impress this character upon the intelligent and sympathetic onlooker. Anybody who, by experiment, is going to discover anything important about the determination of human reactions, must first have developed a certain character of human reaction for himself. If this is to be used against him when he claims validity for his discoveries, it is a sort of stone he can return with some effect, whoever his opponents may be.

Yet it is extraordinarily important that the experimental psychologist should not be exclusively concentrated upon the particular reaction which he is specifically studying. Just because it is the intact subject, the intact organism, that we are concerned with the conditions of any reaction are apt to branch widely. The problem for us, for example, is not to find out how the eye sees or the ear hears, but how the animal and man do. No doubt we can answer this problem only in an imperfect way, but it takes us no nearer perfection to cut the ear or the eye out of the man. This is true with increasing force as we go higher in the level of response. Indirect cues are neither to be ignored, nor to be cut out, but definitely to be studied.

Secondly, no experimental psychologist must profess, with unvarying belief, the dogma of constancy of objective conditions. If, biologically speaking, human reactions had been built up to meet a series of unchanging environments emphatic insistence upon rigidity of conditions would be justifiable. Obviously, they are not so built. So far as the psychologist is concerned, many of the most important characters that dominantly set the course of our reactions belong directly to the organism with which he is dealing, to its immediate and remote past history and to its present specific and general state of adaptation. These intra-organic, or intra-subjective factors may be more diversified by rigidity than by variation of outward circumstance. Of course, I do not argue that the experimental psychologist need not be seriously concerned with constancy of experimental procedure. He must arrange this as carefully as possible, taking advantage of whatever may be known as to the order of importance of the elements of any complex situation with which he is concerned. But he should never hesitate to break this constancy of procedure if his psychological judgment or insight assures him that a diversity of outward circumstances will best secure a relative stability of attitude in his observer. To the experimenter who is not a psychologist this claim may appear arbitrary and arrogant. There is, so far as I can see, no help for that.

In the third place, the position which I have stated carries with it that the experimental psychologist, at the end of his studies, has to be satisfied with indicating trends, directions, proclivities rather than dogmatic laws. His phenomena are essentially biological, in process of development, displaying no hard and fast boundaries anywhere. He may formulate dogmatic laws, and use experiments as imperfect illustrations; but this is the wrong order of things, though it has been by far the commonest and is still the easiest.

Finally there is the question of the relation of the results of specific experimentation to the claims of general systematic theorising. It should be clear that I am not for one moment for the haphazard experiment that has no idea, no broadly formulated problem, behind it. Also I would condemn as heartily as anybody that scatter of descriptive results, uncoordinated, unsystematised, which is common in many directions nowadays. We must explain our results and not merely collect and exhibit them. Yet I would urge that when we have, for example, satisfactorily stated the conditions of some particular perceptual reaction, we have no more right to pronounce magisterially upon a complex problem of reasoning than a physiologist who has studied respiratory functions has to pretend at once to clear up the secrets of spinal reflexes. No doubt the physiologist would never for a moment attempt to do this, but unfortunately it is not so easy to answer for the pretensions of the experimental psychologist in a like case. It may even be that all our specific studies will lay bare common broad principles of the determination of response. Even so, the broad principles are not the explanation of the specific problem, and for whatever they may be worth, before we erect them into a comprehensive system we must have the specific problems widely and patiently worked out.

With this outlook of mingled boldness and caution I believe that experimental psychology will prove adequate to its task of building up a sound scientific study of complex response in animal and man.

SECTION K.—BOTANY.

BOTANICAL RECORDS OF THE ROCKS: WITH SPECIAL REFERENCE TO THE EARLY GLOSSOPTERIS FLORA.

ADDRESS BY

PROF. A. C. SEWARD, Sc.D., LL.D., F.R.S.,
PRESIDENT OF THE SECTION.

INTRODUCTORY.

It is reasonable to assume that when my fellow botanists invited me to preside over Section K at the South African Meeting they were prepared to take the risk of listening to an address which might fail to interest students of other branches of Botany than that which makes a special appeal to myself. It would be little short of an impertinence for me to air my views on problems outside the domain of palæobotany: in these days the average man cannot hope to keep in touch with new developments within any one of the Natural Sciences unless he is prepared wholly to devote himself to reading the contributions of others. For most of us it is necessary to choose one of two courses: either to remain comparatively ignorant of recent advances in most branches of a subject, and to employ such leisure as we can command in concentrating attention upon one small portion of a subject with the determination to make contributions to knowledge, which in moments of elation may be called original; or to qualify ourselves for the title of botanists by doing our best to develop the acquisitive spirit and the ability to assimilate innumerable facts, aims familiar to students preparing for a final examination. One may succeed, after many years of pleasant labour in a restricted field of work, in reaching a stage at which the confidence of youth gives place to a maturer and less optimistic frame of mind: the longer we question Nature the more difficult it seems to obtain clues which we are capable of interpreting with an assured conviction. It is not that the pleasure of the search diminishes: the pleasure persists unimpaired; but it becomes associated as time goes on with a growing sense of ignorance and of doubt. We prefer to make suggestions rather than to indulge in prophetic utterances.

It is not my intention to-day to discuss in detail and in language intelligible only to specialists some of the many problems familiar to students of ancient floras; my aim is to touch as lightly as possible on a few topics which have stimulated my own imagination, in the hope that I may succeed in persuading others that the records of the rocks, meagre though they are, are well worthy of attention; not only on the part of professional botanists but of laymen who wish to cultivate a hobby rich

in possibilities. In addressing an audience, most of whom are not primarily concerned with plants that have been dead for millions of years, it is preferable to run the risk of disappointing palæobotanical colleagues by being too popular rather than to weary the majority by an over emphasis of technical detail. Twenty-six years ago as President of this Section I chose an ambitious text and discoursed on 'Floras of the Past: their composition and distribution,' a theme which, if adequately treated, would occupy more than the whole time allotted to a British Association Meeting. To-day, as befits my years, the programme is more modest: it includes a brief consideration of the age of the late Palæozoic Ice Age in South Africa and other parts of the great continent of Gondwanaland; the lack of data relating to a critical stage in the evolution of the plant-world, represented in the table of contents of earth-history by the passage from the Palæozoic to the Mesozoic era; a brief reference to the difficult and attractive problem of fossil plants as tests of climate; and the importance of extinct plants as aids to the understanding of the distribution of living plants over the earth's surface.

We whose privilege it is to visit South Africa, some of us with pleasant recollections of former visits, are not unmindful of the share taken in botanical science by our fellow workers in the southern hemisphere. On this occasion, at least, I can confidently speak for all the visiting members of the Section and assure our hosts of the pleasure it gives us to take part in a reunion which symbolises the brotherhood of science and the oneness of the aim of all whose lives are mainly devoted to the interpretation of Nature. Our interests are diverse and embrace both the present and the past; but we are united by a common bond—a determination to co-operate in the search for the best thing in the world, the discovery of truth, which has been defined as the hypothesis which works best. Whether we succeed or not, we learn that beyond the material reward, which may follow sustained effort, there is a higher reward which comes from communing with Nature, a spiritual influence seldom acknowledged, though none the less an influence which, if we will respond to it, lifts us to a place where the air is pure and the petty prejudices and jealousies of life have no place. My excuse, if excuse be needed, for speaking in this strain is that we who love Science for its own sake resent the implication that those who pry into the secrets of Nature are in danger of developing into mere materialists whose vision of the infinite becomes dimmed.

I take this opportunity of paying a tribute to South African friends to whom I am personally indebted: Dr. Rogers, an old friend of Cambridge days, has for many years submitted to me specimens for identification—by no means always with satisfying results; Mr. Du Toit, who has fortunately fallen a victim to the fascination of ancient floras; and another old friend, Mr. Leslie of Vereeniging, whose kindness and infectious enthusiasm stimulated me many years ago to turn my attention to the records preserved in the older beds of the Karroo system. This country is rich in documents written 'in the ghostly language of the ancient earth,' and there is still a rich harvest to be gathered. The important contributions made by Mr. Du Toit in recent years may be quoted as an admirable illustration of the kind of research which is needed. I hope one result of this meeting will be an increase in the number of geologists and botanists

imbued with a determination to co-operate in taking advantage of the opportunities, which are theirs, of contributing to a fuller knowledge of the evolution of the plant-world than it is possible to obtain from the records of the rocks on the other side of the equator.

It may be helpful as a preliminary to my treatment of certain aspects of plant-life in former ages to glance at a table of contents of the geological history of the world: we can better appreciate scenes from the past if we think of them in relation to their respective places in the sequence of events registered in the earth's crust.

THE EARLIER CHAPTERS OF THE HISTORY OF THE PLANT WORLD.

It is important to remember, especially important when we are trying to follow the course of evolution in the organic world, that the rocks which have furnished the earliest known remains of plants are separated from the oldest known part of the earth's crust by thousands of feet of strata and by some hundreds of millions of years. The foundation stones of the world in the strict sense are unknown: we are still unable to answer the question—'Whereupon are the foundations thereof laid?'

The crystalline rocks classed by geologists as Archæan represent inconceivably ancient land-surfaces on which were accumulated vast piles of detrital material furnished by agents of erosion, and from time to time products of volcanic activity. Plants may have lived on the Archæan, or Pre-Cambrian, continents; they probably did, but as yet we have no certain knowledge of them. We may think of an azoic world, or of a primeval ocean—'the image of eternity'—pregnant with the first germs of plant-life which in later ages developed into the ancestors of terrestrial vegetation, or our imagination may enable us to picture a Pre-Cambrian land occupied by colonies of primitive plants simpler than any so far discovered in the older Palæozoic strata. Passing higher in the geological series to the marine sediments and associated lavas and volcanic ash included in the Cambrian, Ordovician, and Silurian systems, we find clear evidence of the existence of lime-secreting Algæ, the precursors of some of the modern reef-forming seaweeds, and, in Silurian strata, a few traces of plants which probably lived on dry land. It is true to say that as yet we know practically nothing of the terrestrial vegetation of the world before the beginning of the Devonian period. The lapse of time represented by that portion of the earth's crust comprised within the Pre-Cambrian, Cambrian, Ordovician, and Silurian periods is much longer than the duration of all the other geological periods put together. What is the story of evolution hidden in the Pre-Cambrian and in the earlier Palæozoic formations? This is a question which appeals with especial force to the imagination: though it is too much to expect that we shall ever discover the earliest links in the chain of life, we may with confidence expect to find remains of pre-Devonian terrestrial plants which, I venture to think, will surprise us by their relatively high level of organisation. The more we know of the older floras, the more difficult it becomes to form a clear conception of the course of evolution of the plant-world. We are prejudiced in favour of generalised types and primitive ancestral forms, but while among the earliest known members of the plant-kingdom

there are undoubted examples of structure which may be described as more primitive than any we know in the world to-day, we note a surprising resemblance in the general plan of construction between the inconceivably ancient and the most modern members of the plant-kingdom. Attention has been directed by many writers to the recently acquired knowledge of the floras that have left well-preserved samples in rocks of the Devonian period: we speak of Devonian plants as the oldest known relics of terrestrial vegetation; but we cannot believe that in them we have the first of a succession of colonists which spread over the face of the earth. Whether they are regarded as the modified descendants of more ancient types, which evolved in the sea and subsequently accommodated themselves to existence above the tides; or whether we prefer to think of Devonian plants as descendants of Silurian or still older progenitors, the fact remains that their ancestry is shrouded in mystery. Stress has been laid on certain morphological features presented by members of the older Devonian floras; on the other hand, we must remember that the best-known of these extinct plants lived in swamps and under conditions that were favourable to their preservation as fossils. We know only in part: our knowledge is based largely on a particular kind of plant association, which from the nature of its habitat escaped destruction during recurrent geological convulsions; and it is reasonable to assume that there were contemporary associations occupying other situations of which we know nothing. Words used by the late Prof. Bury in reference to the history of human societies are applicable to geological history:—

‘All the epochs of the past are only a few of the front carriages, and probably the least wonderful, in the van of an interminable procession.’

A few plants have been recorded from Devonian rocks in South Africa, but the records so far obtained from beds below the Karroo system are very disappointing. Further research may yield valuable results: it is a laborious task to look for fossils in ground that is mostly barren, though the search is worth making. It is almost entirely from Devonian rocks of the northern hemisphere that our information has been gained: Australia has furnished a few specimens, and a few fragmentary remains have been described from the Falkland Islands.

Leaving the Devonian period we pass to the Carboniferous and Permian periods, and here there is much to discuss which has a special application to South Africa. In the northern hemisphere the rocks of the Carboniferous system tell a fairly clear story: during the first half of the period comparatively deep seas spread over wide areas in North America and Europe in which there slowly accumulated masses of calcareous material, derived mainly from shells of marine organisms and the framework of lime-secreting algæ.

At many localities abundant *disjuncta membra* of plants have been found in sediments deposited in shallow water near the coast-lines, and in volcanic ash flung from craters over forest-clad regions beyond the reach of the sea. This Lower Carboniferous vegetation, though more varied than that of the latter part of the Devonian period, was its direct derivative. Identical genera and identical, or at least very closely allied, species have been found in North Eastern Greenland, in Spitsbergen, in Europe and

North America, in South America and Australia. Dr. Walkom, of Sydney, has recently recorded some early Carboniferous plants from New South Wales which give additional proof of the striking similarity between the Northern and Southern floras. A piece of a *Lepidodendron* stem, discovered several years ago in New South Wales and recently described by Mr. Barnard, is indistinguishable in anatomical characters from a species originally discovered in the Lower Carboniferous volcanic beds of Southern Scotland. Similarly a splendid specimen, from New South Wales, of one of the earliest known Ferns, *Clepsydropsis*, described in an admirable paper by Prof. Sahni, of Lucknow, demonstrates the existence in the Australian flora of a type closely akin to one which flourished in Europe and Siberia. Many other instances of the wide geographical range of early Carboniferous plants might be given: it is evident that during the first half of the period the vegetation of the world, so far as we can tell, was less diversified than it is at the present day. Genera such as *Lepidodendron* and allied forms, *Asterocalamites*, the earliest, well-defined example of an Equisetalean type, *Rhacopteris* and *Clepsydropsis* among the Ferns, *Cardiopteris*, which may be a Pteridosperm, were common to both hemispheres. Here again we lack data from South Africa. Returning to the Northern hemisphere we pass from the Lower Carboniferous rocks, many of which are marine, to the thick series of Upper Carboniferous sedimentary beds and seams of coal rich in remains of still more varied and luxuriant floras. Over thousands of square miles a monotonous landscape of swamps, occasional sheets of open water, in places the sea near at hand, low hills and plateaux clothed with trees; forests on inundated marshes, jungles with no song of birds, and uninhabited by mammals. Groves of Calamites, their strong columns bare below, where branches had been cast off and the bark torn by the expansion of the growing wood within, the tapering upper parts of the stems hidden by closely set tiers of whorled branches bearing star-like clusters of leaves, might suggest to a visitor from the modern world comparison with enlarged *Equiseta*. Trees such as *Lepidodendron* with forked branches forming a crowded mass of needle-studded shoots would at a distance recall some familiar conifers. A greater contrast to the ordinary type of forest tree would be presented by the tall bare stems of *Sigillaria*, some unbranched, others with an occasional fork, the arms soaring upwards with an elongated cone encased in a tuft of Pine-like needles. The handsome *Cordaites*, with long strap-like leaves similar to those of a *Yucca*, would invite comparison with the Kauri Pine of New Zealand. Here and there among the Calamites and *Lepidodendra* would be found Tree Ferns superficially indistinguishable from existing species. There were other Ferns much too small and inconspicuous to attract attention on a general view. A member of Section K wandering through the forests of the Coal Age would be struck by the abundance and variety of plants which to him appeared to be Ferns: some with stems like miniature Tree Ferns, others of lower growth with fronds borne on creeping rhizomes, and possibly some living as epiphytes, their green leaves standing out against the more sombre coloured trunks of supporting trees. On closer inspection he would discover that most of the supposed ferns bore seeds—some small, others larger than hazel nuts—and clusters of inconspicuous spore-capsules filled with pollen. The dominance of these

seed-bearing, Fern-like plants, the Pteridosperms, is one of the more arresting features of the later Palæozoic floras. During the latter part of the Carboniferous period and the first half of the Permian period the vegetation of North America and Europe was more uniform in composition than the floras of the old and new world to-day. Far-travelled members of this northern vegetation were discovered a short time ago in Sumatra and the Malay Peninsula: their geological age is either uppermost Carboniferous or Lower Permian. Prof. Halle, of Stockholm, in his scholarly volume on the late Palæozoic floras of Central Shansi, in China, has shown that some of the vegetation of the Far East agreed closely with that of North America and Europe. The coal seams of China, though probably rather younger in age than the richest seams of Europe and America, consist of the altered débris of forests which had spread across the world.

Before leaving the northern hemisphere attention must be called to the records of a late Palæozoic flora scattered over a broad region stretching from Northern Russia to the Pacific Coast: this flora consists in part of plants generically identical with European and American Permian types associated with *Glossopteris* and other genera characteristic of India and the southern hemisphere. For convenience we may speak of this vegetation as the Kusnezsk Flora, from a Siberian locality where many of the plants were found: its age is Permian, possibly Upper Permian. Though occupying a territory separated only by a short distance from the Shansi region, the Kusnezsk flora has little in common with those to the South and West: its most striking peculiarity is the presence of *Gangamopteris* and some other types characteristic of the *Glossopteris* Flora, which presumably, as immigrants from the Southern Continent, had found a passage across the Tethys Sea.

THE GLOSSOPTERIS FLORA AND THE LATE PALÆOZOIC ICE AGE.

At the stage of geological history we are considering a broad expanse of water—the Tethys sea—formed a west and east boundary between the northern continent and Gondwanaland. Let us now pass across the Tethys and take note of the conditions farther south. In that part of Gondwanaland that is now South Africa no undoubted examples of Lower Carboniferous plants have been found: the lowest beds of the Karroo system, which rest on Devonian or Pre-Devonian rocks, consist of glacial deposits similar to those which are spread over a wide area in South America, the Falkland Islands, India, and Australia. There is proof of a long-continued reign of ice-sheets and glaciers. The occurrence of well-preserved impressions of plants at the base of the old boulder beds at Vereeniging shows that some members of the *Glossopteris* Flora coexisted with the ice. The problem which I now propose to discuss is this: at what period did the Ice Age begin, and what is the geological age of the first phase of the *Glossopteris* Flora? As Prof. Suess said: following the events chronicled in the Coal Measures of the northern hemisphere, in the south, ‘the outlines of a great continent become disclosed to us, and from the closing days of the Carboniferous this remains for a long period one of the most prominent features of the earth, Gondwanaland.’ The most important of recent contributions to the vexed question of the date of the Gondwanaland Ice Age and of the initial stages of the *Glossopteris* Flora is from

Prof. Schuchert, of Yale University—'Review of the late Paleozoic Formations and Faunas, with special reference to the Ice-Age of Middle Permian time' (*Bull. Geol. Soc. America*, Vol. 39, pp. 769-886, 1929). Though this is hardly a suitable occasion for a full discussion of a controversial subject, it is not inappropriate that I should ask my audience to consider a few of the arguments advanced by the distinguished American geologist, also certain pieces of evidence which seem to me worthy of attention. Mr. Du Toit is more capable than I am of dealing with some of the questions under dispute, and I hope that he also will reply to Prof. Schuchert, who believes that both Mr. Du Toit and myself as well as certain other authors hold heretical opinions.

Prof. Schuchert concludes the summary of his views with these words: 'It is therefore certain that the widely spread tillites (that is the old boulder clays) are of Permian time and in all probability of late Middle Permian age. In any event, not even those of Australia can be of Upper Carboniferous time.' He bases this very definite pronouncement mainly on the fossil animals obtained from marine strata associated with the Palæozoic boulder beds. After referring to views expressed by the late Dr. Arber and by myself that 'the lowest beds containing remains of the *Glossopteris* Flora are, in all probability, homotaxial with the Upper Carboniferous rocks of the northern hemisphere,' he adds: 'They believe that while the cosmopolitan Upper Carboniferous Flora was living in the northern hemisphere, the *Glossopteris* one was in existence south of the equator.' My view is that no Upper Carboniferous Flora was in the strict sense cosmopolitan. Prof. Schuchert continues: 'This contemporaneity of the very different northern and southern floras can not be maintained when the floras are checked into the stratigraphical and marine records. We will repeat,' he adds, 'that even though there are in none of the continents of the southern hemisphere, other than the west coast of South America, any known plant-bearing rocks of Upper Carboniferous age, yet in this single occurrence there is at hand a small plant assemblage of the cosmopolitan Upper Carboniferous Flora.' These South American plants were assigned by Mr. Berry to an Upper Carboniferous horizon, but both Dr. Gothan and myself believe them to indicate a Lower Carboniferous age. The glacial deposits are stated by Prof. Schuchert to be one of the finest means of making definite time correlations from continent to continent, but in another place he admits that the scattered tillites of Gondwanaland, though regarded as the products of one glacial age, are not all exactly of the same age. It may well be, he adds, 'that the basal moraines in South Eastern Australia are somewhat older than those of other continents, as maintained by David and Süssmilch; but by no possible chance can the Australian tillites be stretched into the Upper Carboniferous, nor does it seem possible to place them even below the Middle Permian.' Here we have an assertion which challenges criticism. It has been said that 'a sweeping, unqualified assertion ends all controversy, and sets opinion at rest'; but I am sure that Prof. Schuchert will agree, that before accepting an assertion as final we should satisfy ourselves that it rests on sound foundations. I am indebted to my friend Sir Edgeworth David for information on the succession of boulder beds and fossil-bearing strata displayed in a section in the Hunter

River district of New South Wales : this section gives the sequence of events antecedent to and during the existence of the *Glossopteris* Flora. At the base are sediments known as the Burindi series : in some of the beds pieces of drifted *Lepidodendron* stems were found in company with marine shells. Resting on the Burindi series is the Wallarobba conglomerate, a mass of pebble beds 1,500 ft. thick, which marks the initial stage of a great upheaval and the beginning of a new geological cycle recorded in strata included in the Kuttung series. In volcanic material immediately above the conglomerate were found petrified stems and petioles of the Lower Carboniferous European and Siberian fern *Clepsydropsis*, stems of the Gymnosperm *Pitys*, a common early Carboniferous type in the northern hemisphere, and a petrified *Lepidodendron* apparently specifically identical with a southern Scottish species. The Kuttung series, approximately 10,000 ft. in thickness, furnish an impressive record of a prolonged period of volcanic activity, with recurrent quiescent intervals, when the valleys were occupied by glaciers, which have left traces in beds of boulder clay and erratics dropped from floating ice. Leaves of *Rhacopteris* and *Cardiopteris* and casts of *Asterocalamites*, genera characteristic of Lower Carboniferous floras, bear witness to the spread of vegetation under a relatively low temperature and in an atmosphere charged with volcanic dust. A well-marked break both in the succession of fossils and in physical conditions is registered in the rocks at the summit of the Kuttung series : this unconformity is the expression of a crustal disturbance coincident with the appearance of the *Glossopteris* Flora. The Kuttung series is followed in ascending order by a thick glacial deposit : this forms the base of the Lower Marine Series which includes marine sediments and lava flows : at approximately the middle of the Lower Marine Series were found the oldest known Australian examples of *Gangamopteris*, and from a bed near the base of the series specimens of the bivalve *Eurydesma*, a genus recorded also from S. Africa and India. Above the Lower Marine series are the Greta Coal Measures containing *Gangamopteris* and other members of the *Glossopteris* Flora ; then follows the Upper Marine series, which includes two sets of boulder beds indicative of a return of glacial conditions after a long interval. *Glossopteris* and other plants have been obtained from the overlying Tomago and Newcastle series ; and finally we come to a succession of Triassic sediments known as the Hawkesbury series.

The problem is to correlate the rocks exposed in the Hunter River section with time-equivalents in the northern hemisphere. The beds below the Lower Marine series, containing the oldest examples of *Gangamopteris*, suggest a Lower Carboniferous age. This view is accepted by Prof. Schuchert who, however, regards the break between the Kuttung series and the overlying Lower Marine series as representing the whole of Upper Carboniferous time. He refers the boulder beds and the marine and volcanic rocks of the Lower Marine series to the Permian system. Let us now turn to Western Australia in search of further evidence afforded by marine fossils : there we find a coal-bearing series known as the Collie Coal Measures and regarded as the equivalent of the Newcastle series of New South Wales. In another area, below the Collie Coal Measures, there are glacial deposits resting on the Irwin Coal Measures, the equivalent of the Greta Coal Measures of New South Wales. Beneath the Irwin Coal

Measures are beds with marine fossils which Sir Edgeworth David states indicate a Lower Permian or Upper Carboniferous age. These beds rest on marine sediments rich in the shells of a Cephalopod, *Paralegoceras Jacksoni*, remotely connected with the living *Nautilus*: this Cephalopod is interpreted by Dr. Dighton Thomas as evidence of an Upper Carboniferous age.

The evidence furnished by the Australian sections indicates the existence of a flora, which in the northern hemisphere is accepted as Lower Carboniferous, at a stage followed by strata which have furnished the oldest members of the *Glossopteris* Flora. The break in succession at this level, between the Kuttung and Lower Marine series, is regarded by Schuchert not merely as evidence of shifting of the scenes inaugurating a new type of vegetation—the *Glossopteris* Flora,—but as representing a long interval of time during which rocks of Upper Carboniferous age were being deposited in the northern hemisphere. It is difficult to believe that events which occurred during the latter half of the Carboniferous period are entirely lacking in the geological records not only of Australia, but of India and South Africa. The more probable view, in my opinion, is that the Lower Marine Series and the corresponding strata in Western Australia containing *Paralegoceras* are homotaxial with the Upper Carboniferous system in Europe and North America.

There has been much discussion on evidence relevant to the age of the Glacial period and the *Glossopteris* Flora, derived from the Indian Peninsula and from regions farther north. In the Salt Range a boulder bed, believed to be the equivalent of the Talchir tillite of the Peninsula, is overlain by rocks containing marine fossils including *Eurydesma*, which, as stated later, favours an Upper Carboniferous age. Resting on these beds—the Speckled Sandstone—is the Productus limestone with Permian marine fossils. In Kashmir *Gangamopteris* was discovered low down in a thick series of beds overlain by strata known as the Zewan series, the lower portion of which is probably Lower Permian, if not Upper Carboniferous in age. Prof. Schuchert, after mentioning the discovery of *Gangamopteris* and *Glossopteris* 'in marine strata beneath fossils of the Productus limestone,' goes on to say that this discovery proves that the *Gangamopteris* Flora is of Upper Permian time.¹

The age of the Productus Limestone is a determining factor in Prof. Schuchert's contention, and as the evidence is outside my own province I consulted Dr. Dighton Thomas, of the British Museum, who has made a special study of the palæozoological data bearing on the correlation and age of the Carboniferous and Permian rocks with particular reference to the problems under dispute. Dr. Thomas points out that 'the question of the lower limit in age of the Productus Limestone series, and of the beds below them as far as the boulder bed, hinges on the means of determining the age of the Amb to Virgal series [of the Salt Range].' In his letter of April 19, from which he kindly allows me to quote, he goes on to say that the best means of settling the age of the Salt Range beds is

¹ For a full discussion of the evidence bearing on the geological age of strata in the Salt Range in Kashmir and other districts, reference should be made to two Presidential Addresses delivered respectively by Prof. Sahni and Prof. Das-Gupta at the Eighth and the Fifteenth Indian Science Congresses.

furnished by the Brachiopods, a group which Prof. Schuchert 'practically ignores.' 'If the Brachiopods of the Amb beds (*i.e.* essentially the Lower Productus Limestone) are considered, then one of the noticeable features is the affinities of the fauna to that of the Uralian [Upper Carboniferous] and Artinskian [Lower Permian] of the Urals.' The evidence of the Brachiopods 'would point to the Amb series being of Lower Permian age at the latest, and I cannot agree with Schuchert's reference of these beds to the Upper Permian.' It follows that the underlying Speckled Sandstone, classed by Schuchert as Middle Permian, are 'of high Carboniferous age': 'hence,' he continues, 'the fauna of their lower part, *i.e.* *Eurydesma cordatum*, *E. globosum*, *Conularia laevigata*, etc., is also of Upper Carboniferous age.' In the same letter Dr. Thomas quotes the following statement by Prof. Schuchert: 'The interregional correlations are made, however, not so much from the evolution of the Brachiopods as from that of the Ammonites,' and, Dr. Thomas adds—'But there are no Ammonites in the succession under dispute in New South Wales, nor are there any in the whole Salt Range Series between the boulder bed and the base of the *Xenaspis carbonarius* zone; nor in South Africa, nor in South America.' In his discussion of the age of the Australian beds, Schuchert includes in a list of fossils *Agathiceras micromphalus*, which he regards as a member of an ammonoid fauna. Dr. Thomas says: 'A few years ago I examined together with Dr. Spath the specimens in the British Museum sent over as that species. They could equally well be Bellerophontids. At the same time Dr. F. W. Whitehouse, of Queensland, examined as many specimens as he could in Australia. I do not know if he was able to examine the type-specimen, but in a recent letter to me he stated that about three-and-a-half years ago he published in Australia a note to the effect that the fossil called *Agathiceras micromphalus* is not an ammonoid but a bellerophontid.' Dr. Thomas, in another part of his letter, points out that Schuchert does not attempt an analysis of the fauna of the Australian Irwin River beds, and adds: 'I am quite convinced that the glacial beds there are of Upper Carboniferous age and that *Paralegoceras Jacksoni* is of Uralian age too. Nor does he consider the tillite of Barreal, Argentina, which Reed has shown to be of Uralian age.'¹

I have quoted only in part from Dr. Dighton Thomas's letter in the hope that he will publish in full his criticisms of Prof. Schuchert's views.

In another region, the district of Spiti in the Punjab, some fragmentary plant remains including a *Rhacopteris*, identified by the late Prof. Zeiller as Lower Carboniferous, were found in beds assigned to the Po series. Above these rocks occur shales with marine fossils, which are regarded as homotaxial with the lower part of the Zewan series of Kashmir, and probably either Lower Permian or Upper Carboniferous in age. In the Peninsula of India the beds which contain relics of the *Glossopteris* Flora and the Talchir tillite are almost entirely of freshwater or terrestrial origin, but in 1921 some marine fossils were found in Central India above the Talchir boulder bed. Prof. Schuchert, in referring to this important discovery, expresses the opinion that the marine beds may be 'of the earliest Productus limestone time,' that is in his view Upper Permian.

¹ See Du Toit: *A Geological Comparison of S. America with S. Africa*. (Carnegie Instit., Washington, 1927.)

On the other hand, Dr. Fermor, in his Report published in the Records of the Geological Survey of India in 1921, says 'the discovery at Umaria provides evidence of the presence of the sea in Carboniferous time over a portion of what is now the Rewah State.' Dr. Cowper Reed, who described the Umaria fossils, considers that a marine invasion occurred 'in Permo-Carboniferous times,' and adds that there is a noticeable admixture of types possessing affinities with both Carboniferous and Permian species. The Umaria beds furnish the only piece of evidence bearing on the age of the Talchir tillite, from the Peninsula, based on marine fossils: so far as it goes it does not support Prof. Schuchert's contentions that the Ice Age and the *Glossopteris* Flora are of Middle Permian age.

We now pass to South Africa: as already stated, at Vereeniging impressions of *Gangamopteris* were found between the base of the Dwyka boulder bed and the underlying Pre-Devonian platform. The Dwyka shales above the tillite have yielded *Eurydesma* and a crustacean, *Pygocephalus*: the latter is believed by Mr. Woods of Cambridge to indicate an Upper Carboniferous horizon. Prof. Schuchert attaches no importance to the crustacean. At a higher level is the so-called White Band, which, as Mr. Du Toit points out, affords a valuable connecting link between the South American and South African succession of strata. An important consideration raised by the South African beds is the occurrence at Vereeniging of *Glossopteris* and *Gangamopteris* with *Lepidodendra*, *Sigillaria*, and *Psymphyllum*, which furnish a strong argument in favour of an Upper Carboniferous or at latest a Lower Permian age. An assemblage of plants such as that discovered by Mr. Leslie at Vereeniging has never been found in Middle Permian beds: but Prof. Schuchert definitely states that the tillites which occur below the Vereeniging plant beds are not older than Middle Permian. A collection of plants recently submitted by Dr. Maufe to Mr. John Walton includes species of *Glossopteris* in company with several forms of *Sphenophyllum*, *Pecopteris arborescens* and other plants: comparison with northern floras indicates an age which is at the latest Lower Permian and not improbably near the top of the Upper Carboniferous. The evidence furnished by these and other South African plant-beds is directly opposed to Prof. Schuchert's view. Time does not admit of more than a passing reference to the evidence obtained from South America: this has been fully and ably discussed by Mr. Du Toit in the volume published by the Carnegie Institution. The discovery by Mr. Du Toit of specimens of *Cardiopteris* in Argentina above a tillite, which lies on a glaciated surface, supplies a weighty argument in favour of the Carboniferous age of the oldest phase of the *Glossopteris* Flora.

This summary, though necessarily very incomplete, may enable us to reconstruct in broad outline the closing scenes in the Palæozoic era on the continent of Gondwanaland. We see an enormous land-region comparable in its mantle of ice with Greenland at the present day: in some places glaciers piled up moraines, and their streams deposited seasonally banded mud and sand; in other places, from the cliffs of an ice-barrier, were detached icebergs carrying boulders that found a resting place in the mud of a sea-floor. In the course of the latest phase of the Palæozoic era, ice-sheets and glaciers spread from the remote south beyond the equator: lands that are now tropical were then ice-bound. The world was divided

into at least two sharply contrasted regions, a northern region where rank vegetation covered thousands of square miles of swamp and low hills, and a vast southern continent where another and less luxuriant vegetation flourished in proximity to retreating glaciers.

An argument stressed by Prof. Schuchert in the presentation of his case for the Middle Permian age of the *Glossopteris* Flora and the boulder deposit is based on the marine fossils, which in some regions of Gondwanaland are associated with the plant-beds. I have endeavoured to show that the only piece of evidence furnished by marine fossils available in the Indian Peninsula is unfavourable to his view. Moreover, the *Paralegoceras* of Western Australia and the South African crustacean *Pygocephalus*, leaving out of account data furnished by the remains of other animals, support the opinion that the *Glossopteris* Flora was evolved before the close of the Carboniferous period. If the *Glossopteris* Flora is not older than Middle Permian, we are left in complete ignorance of the state of the plant world in Gondwanaland during the long interval between Lower Carboniferous and Middle Permian time. The *Glossopteris* Flora, or at least members of it, spread from a southern home as far as the province of the Kusnezsk Flora in Northern Russia and Siberia, where they grew in company with typical Permian plants: at a still later date, as Mr. Harris, of Cambridge, has recently shown, *Glossopteris* established itself as a member of the Rhætic Floras of Southern Sweden and Eastern Greenland. If, as is generally admitted, the Kusnezsk Flora is Permian, possibly Upper Permian in age, this is consistent with a considerably earlier age for the *Glossopteris*-bearing beds of Gondwanaland. There can be little doubt that *Glossopteris* had its origin in the South, perhaps on a Palæozoic Antarctica: it seems reasonable to assume that the long journey from the far south across the Tethys Sea began before the end of the Carboniferous period and was not completed until some time in the Permian period.

There is another point raised by Prof. Schuchert on which a word may be said: he speaks of the *Gigantopteris* Flora of China as being overlain by 'much younger and modified parts of the *Gangamopteris* Flora.' The meaning of this is not clear: the flora in China, of which *Gigantopteris*, with its handsome fern-like fronds, was a member, agrees in general character with the late Carboniferous or early Permian Flora of North America and Europe. So far as I am aware this flora has not been found in China, or anywhere else, in direct association with a *Gangamopteris* Flora. The interesting fact is that to the north of China there existed a vegetation which included members of the *Glossopteris* or *Gangamopteris* Flora, while farther south the vegetation was of the European and North American type.

I have dwelt longer than I intended on certain questions connected with the *Glossopteris* Flora, but the publication of Prof. Schuchert's stimulating, and I would add, provocative article, is my excuse. He has stated his case clearly, though not convincingly, and has collected a mass of material for which many of us are grateful; he has rendered good service by directing attention to a problem which appeals both to geologists and to palæobotanists. We are not yet in a position to make positive statements on the age of the *Glossopteris* Flora or on the precise correlation of the late Palæozoic plant beds of Gondwanaland and those north of the Tethys Sea. More evidence is needed; and I venture to hope that Prof.

Schuchert's contribution will stimulate South African geologists to obtain additional evidence which will bring us a stage nearer to an agreement upon this much-debated question. Meanwhile I am not shaken in my opinion that if we could transport ourselves back through the ages into a forest of the northern hemisphere in the latter part of the Upper Carboniferous period, and thence travel by aeroplane to the land that is now South Africa we should find retreating glaciers and a vegetation in which *Glossopteris* and *Gangamopteris* were prominent plants.

A CRITICAL STAGE IN THE HISTORY OF THE PLANT WORLD.

There is another exceptionally interesting problem on which more light is urgently needed, a problem too formidable to consider in the latter half of an address, but attractive enough to mention as a subject worthy of attention on the part of South African investigations. It is this: the closing stages of the Palæozoic era in the northern hemisphere were marked by widespread crustal displacements; a geological revolution brought into being chains of Palæozoic Alps; the scenes were shifted; the forests of the Coal period were replaced by a less luxuriant vegetation growing under a new set of climatic conditions. Crustal movements are a determining factor in the evolution of the plant kingdom: in other words, geological revolutions afford an impressive example of the co-ordination of the inorganic and organic worlds, a theme which has been elaborated by General Smuts in his fascinating book 'Holism and Evolution.' The vegetation of the early part of the Permian period, though generally similar to that of the latest stage of the Carboniferous period, was relatively much poorer in genera and species. The later Permian Floras were still poorer, and the records of the early days of the Triassic period point to the further development of the arid conditions foreshadowed before the end of the Permian age. Later in the Triassic period the vegetation became richer as the environment improved, but it was a transformed vegetation in comparison with the forests of the Coal Age, a much more modern company dominated by a different set of plant communities. There were connecting links between the Palæozoic and the early Mesozoic Floras, but in the main the two floras differed widely from one another. The more orderly succession of plant-bearing strata in most parts of the southern hemisphere justifies the hope that an intensive and comparative study of the transitional stage between the earliest and the latest phase of the *Glossopteris* Flora will furnish valuable data. In this field of work Mr. Du Toit has shown the way: may his example be followed. The fragmentary documents scattered through the rocks at the boundary between the two eras relate to a critical stage in the fortunes of the plant-world: the discovery of additional records would be particularly welcome.

FOSSIL PLANTS AS TESTS OF CLIMATE.

I now propose to intercalate a few words on another question of general interest. Nearly forty years ago I wrote an essay on a prescribed text, 'Fossil Plants as Tests of Climate,' an essay which was mainly a compilation and not an original contribution. It is unnecessary to remind my audience that fossil plants of many different ages frequently occur in unexpected and, from some points of view, very inconvenient places, where

they raise problems which have so far baffled the ingenuity of students. The best examples are from Arctic regions, and there is also the rich Jurassic Flora described some years ago by Prof. Halle from the edge of the Antarctic region. Prof. Nathorst demonstrated the occurrence on Ellesmere Land a few degrees south of lat. 80°N. of an Upper Devonian Flora in which species of the fern-like fronds of *Archaeopteris* are abundantly represented: it is noteworthy that these fronds—probably the foliage of a Pteridosperm—are in no way inferior in size to those of the same type discovered in Southern Ireland and Southern Russia. Farther south, but still well within the Arctic Circle, the rocks of the desolate and mist-shrouded Bear Island, in latitude 75°N. , have yielded an unusually rich flora which is also Upper Devonian: here, too, well-developed fronds and thick stems of various plants bear eloquent testimony to climatic conditions entirely foreign to European Arctic regions at the present time. The Lower Carboniferous Flora of Spitsbergen compares favourably in the dimensions of the *Lepidodendra* and other trees with floras of the same age in Central Europe. From lat. 80°N. on the North Eastern corner of Greenland, a few fragmentary remains of widely distributed species mark the most northerly outpost of the early Carboniferous floras. Turning to the Rhætic period, the work of Dr. Hartz, of Copenhagen, and the more recent and more extended labours of Mr. Harris have given us a thrilling picture of an estuary bordered by a luxuriant and varied vegetation, which can best be described as a detached arctic outlier of the well-known Rhætic forests of Southern Sweden. Farther east the New Siberian Islands (lat. 75°N.) have afforded samples of Triassic and later floras which give no sign of the stunting effects of Arctic conditions. Many Jurassic plants are recorded from Franz Josef Land, Spitsbergen, and Northern Siberia which include leaves hardly distinguishable from those of the Maidenhair tree (*Ginkgo biloba*), the only surviving genus of a once prolific and cosmopolitan group; also twigs and cones of Conifers, some of which appear to be closely allied to the Californian Sequoias; some recall existing Araucarias and other genera, which long ago deserted their northern home for southern lands. The best known Arctic Cretaceous Flora is that from Western Greenland (lat. 70°N.), a flora especially rich in Ferns near of kin to species of *Gleichenia* that are now mainly tropical in range. Among other Greenland plants are species of *Ginkgo*; Conifers allied to *Sequoia*, *Cupressus*, and other genera; leaves and fruit differing but little from those of the living Bread-fruit tree, leaves believed to belong to a Leguminous plant closely allied to existing species of *Dalbergia*, species of *Magnolia*, many forms of Plane tree (*Platanus*), and examples of other South temperate, sub-tropical, and tropical families.

Relics of Tertiary Floras have been found on Sabine Island off the East Coast of Greenland on lat. 75°N. , in Grinnell Land still farther north, in Spitsbergen, where leaves of *Platanus* have been found rivalling in the spread of the lamina the foliage of existing species on the Adriatic coast, and at many other localities within the Arctic Circle. The most striking instance from the other end of the world is the Jurassic Flora of Graham Land first recorded by Prof. Nathorst and subsequently described in detail by Prof. Halle.

It is superfluous to quote more examples. An important point is that

if we plot on a map of the Arctic regions the distribution of ancient floras, it becomes clear that no shifting of the earth's axis, even if this favourite device were admissible, would give a satisfactory explanation of the contrast between the past and the present. These facts are well known; but it is time we made a more serious effort to solve the problems which they raise. Discarding as inadequate, and as a method wholly displeasing to astronomers, an attempt to create geographical environment consistent with palæobotanical facts by altering the position of the North Pole, we turn to the alternative of rearranging, within the Arctic Circle, the distribution of land and sea and the consequential shifting of cold and warm oceanic streams. Assuming the permission of geologists to treat the earth's crust as a jig-saw puzzle, we appeal to meteorologists. Mr. Brooks in his book on 'The Evolution of Climate' suggests a possible rearrangement of land and water which, he believes, would go some way towards the provision of climatic conditions such as the fossil plants of the Tertiary period appear to demand; but it would seem from a more recent contribution by Dr. Simpson, the Head of the British Meteorological Department, that we cannot hope to obtain all we need, or nearly all we need, by any method of redistribution of land and sea on the assumption of a fixed pole and without recourse to Wegener's hypothesis of drifting land areas. We are left with two other alternatives: the adoption of Wegener's views or some modification of them; or the possibility that plants are less trustworthy as indices of climates than has generally been supposed. It may be that a combination of these two methods of attack is the clue to our problem. Let us take the second first: assuming that the ferns to which reference has been made flourished on the parallels of latitude where their remains have been found, and assuming such amelioration of the present arctic conditions by a rearrangement of land and water as meteorologists permit, there must have been in the past, as there is to-day, a long and relatively dark period of sleep, and a summer no longer than the growing season now available for the almost miraculous development of Arctic plants. Can we imagine, to take one instance, the Cretaceous Flora of Greenland enduring a sunless arctic night more than six months in duration? This raises a question to which no complete answer can be given: we lack experimental data. It would be worth while to take advantage of modern methods of research and devise means of reproducing on a small scale the arctic summer season with continuous illumination followed by a longer period of darkness. In considering possibilities we must not forget the marked difference in the present position of the tree-limit: in some places it dips far below the Arctic Circle, while in others it invades much higher latitudes. In Western Greenland on latitude 70°N. the willows seldom reach a height of three feet; on the same latitude in Canada and Alaska the White Spruce (*Picea canadensis*) attains fifty feet in sheltered places.

There is another, and to my mind an important and neglected consideration; we are too prone to speak of such a genus as *Gleichenia* as tropical because it happens to be one of the commoner ferns in tropical countries; but, like many other genera characteristic of the warmer parts of the world, it includes species which grow vigorously at an altitude of 10-12,000 ft. where the climate is by no means tropical. Is it not legitimate to

suggest that the relation of genera and species to climate to which we are accustomed is merely a phase in the history of plants? A plant that is now confined to the tropics may at a much earlier stage of its career have been able to live under other conditions. In using plants as thermometers of the ages, we accept as an axiom the principle—what is now has always been. Our vision is limited by what we see and beyond the horizon we see only in imagination. Is it unscientific to express the opinion that we may think of plants not only as organisms which have changed in form and structure in the course of thousands or millions of years, but as organisms which have changed also in their susceptibility to external factors? There is another point, and an obvious one; instances are common enough of species of living genera which exist under conditions sharply contrasted with those characteristic of the majority of species of the same genus. The Cretaceous and other plants are practically all specifically distinct from their living descendants—we are not entitled to attribute to extinct and recent alike the same constitutional qualities.

I suggest that there is a tendency to rate too highly the value of extinct plants as guides to climatic conditions, and I would again emphasise the desirability of obtaining more definite information than is at present available on the effect of continuous light and continuous darkness, under suitable temperatures, on plants which do not at present occur in Arctic habitats. Even if the foregoing suggestions have any merit, and if we have underestimated the capacity of plants to survive Arctic seasons, there is still a serious obstacle to surmount before it is possible to imagine, let us say, the Rhætic vegetation of Scoresby Sound and that of Southern Sweden flourishing in regions separated from one another by at least ten degrees of latitude. It seems impossible to get away from the conviction that there must have been in the past as there is now a marked contrast between two sets of contemporary plants, one more than 200 miles north of the Arctic Circle and the other more than 400 miles south of it. The proposal to regard the present land-surface as a portion of the earth's crust which has not only changed its form in the course of geological history, but as a collection of slabs slowly drifting from place to place is no new idea; but we are indebted to Wegener for the development and extension of a theory which in its present form has provided an incentive to speculative minds and, it may be, a valuable clue to the solution of diverse problems. Wegener speaks of the upper portion of the crust as travelling in an easterly and westerly direction; he also assumes a slight movement of the poles. If it is permissible to postulate a drifting of fractured slabs of the crust in a north and south direction, we can then think of the disunited pieces, now occupying positions more or less remote from one another, as the severed portions of a formerly compact region. To take a concrete example: the Rhætic plant beds of Eastern Greenland, now remote from those of Sweden, may formerly have been portions of one mass well to the south of the Arctic Circle. This may be merely a figment of the imagination: on the other hand, some such expedient is almost forced upon us if we are to find a solution to the problem presented by the records of the rocks. There are, we are told, serious objections to Wegener's hypothesis: it is at any rate true that the principle of drifting continents has still to be proved tenable. But such evidence of correspondence, both

in the succession and nature of the stratified rocks and in the fossil contents, as Mr. Du Toit has obtained from a comparative study of the rocks of South America and South Africa, or as Mr. Harris is finding in his comparison of the Greenland and Swedish Rhætic Strata, is arresting enough to make us pause before abandoning the principle of continental drift.

PALÆOBOTANY AS A KEY TO THE PRESENT DISTRIBUTION OF PLANTS.

If time allowed it would be tempting to deal with still another aspect of Palæobotany; the importance of a critical study of the floras which immediately preceded the Pleistocene Ice Age. Progress made in recent years in the improvement of methods of deciphering the relics of plants of other days increases the confidence with which it is possible to recommend, as a promising field of work, the investigation of Tertiary Floras. There are few more fascinating lines of research than those leading to a fuller knowledge of the wanderings of plants over the earth's surface. It is only by following the varying fortunes of genera and species during the successive stages of the Tertiary period that we can hope to understand or to explain the present distribution of plants. Let me give one illustration: the work of Mrs. Clement Reid and Miss Chandler, as well as the results obtained by many other palæobotanists, has brought into relief the destructive effects of the conditions which culminated in the last Glacial period. We know that the floristic characters now distinguishing European Floras from those of North America and China are in no small degree the direct consequence of the Ice Age: this caused the elimination from the European area of many plants which, had they survived, would give a greater uniformity to the vegetation of the northern hemisphere than there is at present. In North America and in Asia the way was open; the northern species were able to migrate far to the South and thus escaped the fate of their companions which were unable to cross the barrier of the Alps and the Mediterranean Sea.

The Tertiary Floras were more uniform than the floras of to-day. We cannot understand the present distribution of human races if we confine attention to the present, nor can we appreciate the significance of the geographical distribution of floras and their composition unless we consult the herbaria of the rocks.

CONCLUSION.

These are but a few of the promising fields of work open to students of ancient floras. I do not wish to be thought an advocate of extreme specialisation; my desire is to see a wider recognition on the part of geologists and botanists, whether professionals or amateurs, of the value of palæobotanical studies in relation to problems of general interest. The layman is often deterred from serious application to any branch of science by the length of the road he thinks it will be necessary to travel before becoming qualified for research. If it were essential to master a subject before attempting to contribute to its advancement by original work, none of us could hope to become more than industrious seekers after omniscience within a restricted field. Anyone of average intelligence, provided he or she has the driving force born of enthusiasm and the

faculty of taking pains, is capable of making valuable contributions to knowledge in some department of scientific enquiry. Amateurs have taken an honourable and productive part in advancing geological and botanical knowledge ; they have an advantage over professional teachers in that they are free to concentrate their energies where preference leads them. Moreover, laymen are more fortunate than professional men of Science, who are expected to be able to answer all questions relating to the subject they profess, in not being expected to know more than they know. To-day the opportunities of making acquaintance with the Natural Sciences are much greater than they were a few years ago, but the number of men and women who become keen enough to cultivate any one subject as a hobby is relatively small. I may be accused of closing my address in words more appropriate to the pulpit, but none the less I venture to urge upon teachers of science the duty of doing their utmost to awaken the souls of their pupils, to introduce them by means of simple examples to the joy that is to be found in putting questions to Nature and in trying to extract answers. It is of secondary importance whether we find answers or not :

‘ I question things and do not find
One that will answer to my mind.’

It is the passion for the search that matters. Science should be taught not so much in preparation for a profession or a business ; it should be presented in a form calculated to develop an interest strong enough to make a permanent impression on receptive minds. We need helpers in the cause of research, and it is for us who are engaged in teaching to make clear to those within our sphere of influence the saving grace of a deeply rooted interest in life over and above our daily duties, which will serve not only as a means of advancing natural knowledge but as a guiding star. Facts are the tools with which the man of Science works, but to use them to the fullest advantage he must be able to respond to the inspiration which comes to him who can look beyond the edge of the world :

‘ Father, O father ! What do we here
In this land of unbelief and fear ?
The land of Dreams is better far,
Above the light of the morning Star.’

SECTION L.—EDUCATIONAL SCIENCE.

MODERN MOVEMENTS IN EDUCATION.

ADDRESS BY

C. W. KIMMINS, M.A., D.Sc.,

PRESIDENT OF THE SECTION.

THE meeting of the British Association in South Africa in 1905 was in many ways a memorable one. The Education Section was particularly fortunate in having as its president a remarkably distinguished scholar, Sir Richard Jebb, whose presidential address on 'University Education and National Life' made a profound impression on the crowded audiences who heard it at Cape Town and later on at Johannesburg. The papers read at this meeting dealt with a great variety of subjects, including 'The Teaching of Science,' 'Technical Education in a New Country,' 'The Teaching of Modern Languages,' 'Manual Instruction,' 'The Teaching of Agriculture,' 'Rural Education,' 'Recent Improvements in the Education of Infants,' and the renowned Dr. Murray, of dictionary fame, delighted us all with his paper on 'The World of Words.' The English visitors were deeply interested in the important papers read by well-known directors of education in this country on such subjects as 'Cape Education,' 'Native Education,' 'Progress of Education in the Transvaal,' 'Education in the Orange River Colony,' 'Education in Rhodesia,' 'Education on the Veldt,' and 'The Higher Education of Women in South Africa.'

The progress in education of recent years has been positively bewildering—greater, in fact, than at any period of our history—and it occurred to me, in thinking of an appropriate subject on which to address you, that it might not be without interest to deal briefly with some of the more important movements which have emerged during the interval which has elapsed since the former meeting in South Africa. In doing this I will avoid matters of local interest and treat only of those of general application in educational procedure.

One of the most significant movements is the change of attitude towards the mental development of the very young child. Until comparatively recently, the physical condition of the child up to the age of six years was the only matter that appeared to need serious attention. Educationists and psychologists now, however, at long last, fully realise that the period from two to six years of age is far and away the most important of the child's life. In other words, there must be a really sound foundation if a satisfactory superstructure is to result in the child's development. The mental as well as the physical welfare of the young child must receive adequate attention. The reliable evidence we possess that many of the cases of serious mental trouble in later life may be traced to unwise

treatment in early childhood is a case in point. During this period of active habit formation, when the necessary sublimation of nascent instinctive impulses is relatively an easy matter, the value of intelligent guidance is too obvious to need further mention.

As if to make up for the neglect of past years of the importance—the extraordinary importance—of a fuller knowledge of the beginnings of education and the dawn of intelligence of the young child, there has been of recent years a concentration of investigation on this period by distinguished experts, which has fully compensated for the lack of adequate research in earlier times. The manifest difficulty of discovering by direct observation how the very young child approaches and overcomes obstacles in the great adventure of becoming acquainted with the nature of his strange environment, has to a very considerable extent been aided by experiments with the more intelligent animals.

The classical researches of Köhler in his arduous and remarkably successful work, an account of which is given in his fascinating book on 'The Mentality of Apes,' have cast a flood of light on the learning process. The valuable monographs of Prof. Yerkes on 'The Mind of a Gorilla,' in which he describes his investigation of the process of learning in this animal, confirm and to some extent further elaborate the experiments of Köhler. The great value of this type of investigation is that tasks of varying difficulty can be given to the animals, such as the improvement on repetition, the memory of success in an earlier experiment in attempting a more difficult task of the same nature and so on, can be carried out and conclusions reached. Obviously, it would be impossible to make a young child go through a long series of conditioned experiments, and thus acquire a knowledge which can be obtained so readily by experiments with animals. When isolated experiments of a like nature were carried out with young children, the similarities of response and the means adopted in reaching the desired end were very significant.

The fact that Koffka in his interesting book on 'The Growth of the Mind'—which is an admirable introduction to Child-Psychology—gives such prominence to Köhler's work, is indicative of the value he attaches to it. His statement in this connection is of interest:—

'If chimpanzees are able to solve original problems, not merely by chance, but with insight, then the behaviour of these animals ought to throw new light upon the nature of insight; for modes of behaviour that have become a matter of course with us adults may be expected to appear in a more plastic form in the life of an ape. If the simplest acts of intelligence can in this way be brought under scientific experimental observation, the results must yield important data for theoretical purposes. With adult man, on the contrary, an investigation of the simplest acts of intelligence is no longer possible.'

'Since Köhler's experiments provide us with the kind of information we need, we shall find it worth while to examine them in detail. Indeed, they furnish us with a significant contribution to the solution of our chief problems, namely, the nature of *learning* in general, and the origin of the first *problems of achievement* in particular.'

The remarkable difference which exists between the child's world and that of the adult presents very serious difficulties in the study of young

children. This has, in the past, given rise to much serious misunderstanding as to the real attitude of the child to life. A fertile source of this difficulty is to expect a child to adopt the adult position before the appropriate time in his mental growth has been reached. Long after speech has been acquired, the meaning of a simple expression, in exactly the same words, may convey to the mind of the child something entirely different from the meaning which it conveys to the mind of the adult. Much work in this connection has been carried on in recent years with considerable success. Many attempts have been made to summarise the main points of difference between the two worlds. An account of an effort of considerable merit in this connection is to be found in the final chapter of 'The Growth of the Mind' entitled 'The World of a Child.' Something more than a summary, however, is needed in a matter of such importance. In the account of the researches of Prof. Jean Piaget and his colleagues in the University of Geneva, as the result of many years of patient and detailed investigation, we are fortunate in having a fairly complete and absorbingly interesting study of this hitherto comparatively unworked field.

It would be difficult to over-estimate the value to the student of early child life of the records of these researches in 'Language and Thought of the Child,' 'Judgment and Reasoning in the Child,' and the recently published volume on 'The Child's Conception of the World.' The powerful influence of egocentrism in the young child is well known, and the replacement as it wanes by other mental elements is discussed probably with a greater clearness and confidence than in any previous attempt in this direction.

The published work of the original investigations of Prof. and Mrs. Stern, and that of Prof. Arnold Gesell, are also valuable contributions to our knowledge of this period.

The astounding progress made in the interval of time under review, in our knowledge of the pre-school child, must be referred to not only for its intrinsic importance, but also because original work at this stage of development has had such a beneficent effect in popularising education, especially in its social implications. In the school we have a sufficiently large number of children for observation, and possibly for experiment. We can generalise and compare group with group. But the pre-school child is a thing apart, and the nursery is the nearest approach to the classroom. On the physical side the pre-school child is within reach of experts. The local doctor, the mother and the nurse or other attendant possess, or should possess, a fair knowledge of childish ailments. On the mental side, however, there is a lamentable deficiency of anything in the nature of expert guidance. The general opinion being that this side of the child's development can safely be neglected until the child goes to school.

We have already pointed out the folly of such a generalisation. The pre-school period is singularly rich in the opportunity it offers for wise, expert assistance. Parents, however, are now beginning to realise how remarkably clever their young children are, and what native ability they possess of overcoming obstacles which present themselves. The following example recorded by a skilled observer is a case in point:—

'Age two years and twenty-three days. This is an example of thinking

out a problem. His mother was using a sewing machine in the dining room, and he got into a chair beside her and hindered her by persisting in turning the handle. I came in, took him on my knee, and kept him still. He got tired of this, clambered down, took my hand and pulled me, saying, "Teeune on ze moosical box." I took him to the library to start the gramophone. As I opened the door he disengaged himself, and saying "By yourself, daddy," bolted back to his mother and the machine. He had evidently worked out a way of getting rid of me.'

This boy of two years and twenty-three days clearly decided that he must get rid of his father, who stood between him and the sewing machine, in which he was so much interested. He laid a trap for his father, into which he fell, and gained his point.

The period of about three to six years of age is characterised by abnormal imaginative power. This is at the stage at which the invisible friend or other childish fantasy makes its appearance. At three years of age the child fully recognises himself as a separate entity in the environment. It took him a long time to recognise that the teddy-bear and the golliwog, in whom he confided, had no power of understanding or of effective response, and then the visible inanimate was replaced by the invisible animate of childish fantasy.

Prof. Sully, in his 'Essay on Laughter,' gives an interesting account of early playing with words. His little daughter, on her third birthday, heard her mother say, 'Mr. Fawkes is coming to lunch,' and the child said, 'I hope Mrs. Knives will come too.' The statement was criticised, as it was thought that at such an early age a child would not consciously play with words and make a definite pun, but investigations of sayings of young children prove that a love of playing with words frequently enters into the child's life with the introduction of new words into his vocabulary. He plays with a new word as he would with a toy in the nursery, and this serves the very useful purpose of leading him eventually to the true content of the word. In the process, however, the misplacing of it in many connections gives rise to the quaint sayings which cause so much amusement in childish *naïveté*.

During the imaginative period the child delights in making up stories. Many of those which have been recorded exhibit a very remarkable ability in this direction. A good example of this is given in a singularly charming little book 'Behind the Night-light,' by Nancy Price, whose little girl at the age of three years would look into the fire and tell her mother what she saw there. The stories were so interesting that they were translated into ordinary language—with no additions or changes in content of any kind—and published. This faithful record shows not only that the child had the power of constructing very interesting narratives of delightful originality, but that she also had a dawning sense of humour.

A careful study of childish *naïveté* affords ample evidence of the very considerable ability of the pre-school child. It reveals interesting glimpses of the mental make-up, the quaint judgments, the curious application of words the true meanings of which are imperfectly understood, and the child's sense of justice. In many ways such a study is far more interesting than that of the school child whose submission to authority has somewhat diminished his originality and standardised his outlook on life.

The greatly increased interest in the mental welfare of the young child has naturally resulted in a renewed demand for a better provision of institutions, such as nursery schools and kindergartens, concerned with the care and education of pre-school children with a range of age of two to six years.

In the Fisher Act of 1918 ample provision was made for the recognition and support of nursery schools and classes. This gave great satisfaction to all students of early child life and those interested in the welfare of little children. Then came the Geddes axe. The increased national expenditure involved in the changes adumbrated in the forward movement in educational procedure in the various sections of this beneficent Act met with considerable opposition on the grounds of financial stringency. This veritable Children's Charter came under the ban of the economists, and up to the present time there has been no possibility of the full development of the scheme. The power, however, of the adequate fulfilment along the necessary lines suggested remains on the Statute Book, and the demand for its greater exercise is now becoming insistent. An effort is now being made to make the provision compulsory. The Chief Medical Officer of the Board of Education in his valuable annual reports on 'The Health of the Child' consistently urges a move forward in the establishment of nursery schools.

The difficulties which have been pointed out of reaching, and of giving effective guidance to children at the more plastic and formative pre-school period would, to a considerable extent, be removed if the nursery school became a recognised constituent in the educational provision of each district. In a centre which is fortunate in having a good nursery school within its area, the remarkable influence of such an institution is obvious to the most casual observer. With such very young children on the roll, this type of school comes into far more intimate contact with the home than any other agency. The atmosphere of the school permeates the home to the very great advantage of the parent as well as of the child. In many cases the principal and staff of the nursery school become the friends and advisers of the parents in all matters pertaining to the welfare of the children. The intelligent mother tries to raise the standard of the home to the standard of the school.

The importance of linking the home with such an institution as a nursery school cannot be exaggerated. It is far more important in early life than later on. Continuity in the type of experience is essential in the successful nurture of the young child. A further advantage of the nursery school is that children come into contact with other children of the same age. It is a misfortune for a young child to be always in the presence of adults. The outlook is so different. A gulf separates, as we have seen, the child's world from that of the adult, and to adopt, at too early a stage, the adult attitude to life is to rob the child of the priceless advantage of his childhood. Children can readily understand children and learn far more from each other, and in a more natural way, than from an adult source.

The teacher at the nursery school is, or should be, an expert in the management of children. The mother from a poor home, who is concerned with the riotous behaviour of her children, is impressed by the quiet

joyous atmosphere of the nursery school and, seeing how it is attained, may learn her lesson. She discovers that for the riotous conduct in the home she is not free from blame, and if she is wise she will change her method of treatment. It is useless, however, to blame the parents. This point is well put by Prof. Helen Woolley of Columbia University, who was formerly director of one of the most famous nursery schools in the world, the Merrill-Palmer School, Detroit: 'One cannot expect every mother to be an expert in educational methods for children between two and five, any more than we expect every mother to be an educational expert in methods for children between five and ten years of age. In fact, at present the younger period is rather the more difficult, because it is not so well understood and not so well standardised as educational work for older children.'

The whole problem of the pre-school child presses for solution. The difficulty is that although parenthood is the most important profession in the world, there is at present no specific preparation for it and there is no immediate prospect of a higher standard of parenthood. Yet it is clear that in dealing with the young child there is a distinct need of expert guidance. If, however, the home and the nursery school work together the problem-children—who eventually may become a burden on the State—will rapidly decrease in number. There can be no doubt whatever that with a well-organised nursery school system there would be a significant advance in the mental, physical and social welfare of the children.

I must mention in passing another movement of which we shall hear a great deal in the near future. It is 'The Child Guidance Clinic' which is powerfully supported in America and elsewhere by 'The Commonwealth Fund.' The function of the clinic is to look after the interests of mental hygiene among children in the area in which it is established. In a fully developed clinic the staff consists of psychiatrists, psychologists and a fully-trained body of expert investigators. Under ideal conditions, the clinic has an independent existence and aids the various agencies interested in the welfare of children within the sphere of its operations. Its main objective is to formulate in a scientific way 'the rules of mental health and the ways and means by which mental health may be gained or increased.' Among its various activities are the following: the study of abnormal children, systematic lecture courses for parents, and educating teachers in mental hygiene. The purpose of the clinic is not to compete with established work but to supplement it where necessary by co-operation.

Experiments which are being conducted in America on the lines of the child guidance clinic, vary in different localities. Experts from several countries have reported very favourably on the results of the work of the clinics and advise the adoption, frequently in a modified form, of similar organisations in the countries they represent.

Clinics having a similar objective, but with a less ambitious type of organisation, have been in operation in England and Scotland for some years, and through the generosity of the Commonwealth Fund a child guidance clinic on the American plan has recently been started in London.

The chief value of the clinic lies in remedial work, that is, in repairing damage to the mental health of the children caused to a large extent by

improper treatment during the pre-school stage. With a fully-organised system of nursery schools the production of such maladjustments would largely be avoided, and if there happened to be a clinic within reach to which any serious difficulty might be referred, the needs of the district as regards mental hygiene would be met. Attention given to prevention would give far greater promise of ultimate success than the more elaborate and costly curative provision.

Apart from the new attitude to the pre-school child the most important movement since 1905 is the coming of the Intelligence Test and its incorporation as an essential element in the general scheme of education. Probably more research has been carried out in recent years in connection with tests for intelligence than in any other department of educational activity. Even if only rough approximations could be secured in the measurement of native ability, nevertheless, the advantage of such a discovery would naturally make a very strong appeal to the minds of progressive educationists. The researches of Binet and Simon clearly pointed the way to the attainment of a means of estimating innate intelligence. As a consequence, the Binet-Simon Scale has been the starting point for an enormous amount of original research on a subject which was destined to yield a rich harvest to the investigator if a really satisfactory working method of testing native ability could be obtained.

Various Revisions of the Scale have been adopted in different countries, and improvements have been, and are still being, made. We are as yet very far from having reached the ideal form of intelligence test, but sufficient has already been done to show by actual experience, in a variety of ways, the remarkable value of individual and group tests.

In 1924, as a result of a very careful investigation by the Consultative Committee of the English Board of Education, a Report was published with the somewhat repellent title of 'Psychological Tests of Educable Capacity.' From many points of view the Report is of considerable importance and value. The Committee consisted of a body of well-known educationists and administrators, but it contained no member who could be regarded as a psychologist. The result was that the report was based on the evidence of distinguished experts in psychology who came before the Committee and who could speak with great authority on the subject of intelligence. The conclusions thus formed, by men and women with no special bias in favour of intelligence tests, were naturally unprejudiced, and the report therefore can be relied upon as a cautious statement of the position which is not calculated to over-estimate the value of this new factor in the scheme of education.

The following extracts from the report are of interest: 'What tests of "intelligence" measure, therefore, is inborn, all-round, intellectual ability, using the word "intellectual" in a loose sense to include practical activities as well as theoretical, but to exclude processes of emotion and qualities of character.' And after making certain criticisms: 'But, with all these necessary reservations, the success and the wide-spread use of intelligence tests remain among the most remarkable achievements of modern experimental psychology.' The value of the Report is much enhanced by an admirable historical sketch of the development of psychological tests which was contributed by Professor Cyril Burt.

Intelligence tests in connection with school organisation are found to be of great value as an additional factor in promoting children from class to class. The following is a good illustration: In a London school in a particularly poor neighbourhood the children for many years had not been successful in obtaining any scholarships in the annual examination for the transference of boys and girls from the elementary to secondary schools. The departments were under excellent management, and the failure to obtain scholarships was ascribed to the poverty of the material entering for the examinations. On the promotion of the head mistress of the girls' department a teacher was appointed to the headship who, apart from her success as a teacher, was keenly interested in intelligence tests. She decided that, in placing the children coming up from the infants' department, she would be guided not only by the reports received of their educational achievement, but also by their native ability as shown by intelligence tests.

The value of this changed method of school organisation was clearly shown when the period was reached at which the children promoted in this way were old enough to enter for the scholarship examination. They gained, for the first time in the history of the school, a fair number of scholarships, and this success was repeated from year to year. That this remarkable achievement was due in large measure to the improved method of classification may be inferred, without hesitation, as the staff of teachers was practically the same as in previous years, and no extra strain was put upon the children.

It is evident that, as there is such a wide range of native ability in boys and girls of the same age, anything in the nature of a rigid chronological basis in school classification must be profoundly unsatisfactory. Not only that; imperfect classification may, and frequently does, inflict very serious injury on the misplaced child. The super-normal boy or girl placed in classes with children of the same age, but of markedly inferior ability, runs a great risk of becoming an exceptionally lazy person, though he or she may without the slightest difficulty be at the top of the form or class, and be the recipient of wholly unmerited praise.

In the *Begabten Schulen* in Germany, where, in the final selection for admission, the results are almost entirely based on the intelligence quotients of the candidates, one cannot fail to be greatly impressed by the ease with which these children, without any undue pressure, can successfully cover as much ground in one year as normal children would require at least two years to accomplish. In the days to come we shall give far more attention to the super-normal child than we do at present. One of the many virtues of the Dalton Plan, which is having a profound effect on English and American education, is that it makes ample provision for the super-normal child.

In the award of scholarships the intelligence test should play an important part. It is not sufficient to judge the candidate entirely by his educational achievement, which may simply have been the result of very careful preparation. It is necessary also to be assured that his native ability is such that he will be able to make good use of the facilities available at the place of higher education for the admission to which he is a candidate.

A very promising direction in which intelligence tests may render invaluable assistance is to be found in vocational guidance. In view of the enormous—and ever increasing—expenditure on education, it is remarkable that until recently so little attention has been given to the successful marketing of the produce of our schools. The ‘after-care’ agencies—frequently voluntary organisations—have done excellent service in various districts in looking after the interests of children seeking employment on leaving school. Their activities have, however, been largely of a social order, involving securing information as to the reputation of firms employing children and the conditions of labour, the possibilities of advancement and so on. The members of such welfare committees often keep in touch with the employees and advise the children when difficulties occur in connection with their employment, which by friendly co-operation can be adjusted.

The frequent changes of employment, which have such a demoralising effect on children, may be diminished to a marked degree in districts which are fortunate in possessing a really efficient after-care committee. The judgment of the school as to the type of employment for which a particular child is suited is also of considerable value. Without underestimating in any way the importance of the beneficent effect resulting from the various after-care agencies on the future welfare of the children, it is evident that if by intelligence, and specially devised vocational, tests a clear statement could be made, on a scientific basis, as to the kind of occupation, or group of occupations, in which a child, on leaving school, may find the fullest expression for any native ability which he is found to possess, it would be of the greatest possible service.

The much-to-be-desired solution of this very difficult problem, which may play an important part in the future happiness of the child, appears to be on the high-road to realisation. In 1926 a report was published of ‘A Study in Vocational Guidance by the Industrial Fatigue Research Board and the National Institute of Industrial Psychology,’ which marks an epoch-making advance in the interests of child welfare. The investigation was conducted under the direction of Professor Cyril Burt.

The subjects of the experiment were all the children in a certain London borough (fifty-two boys and forty-eight girls), who were due to leave school within the next year. Their ages lay between thirteen and fourteen. The investigation included Intellectual Capacity (general intelligence, specific capacities, educational attainments and special interests) and Temperament and Character (emotional, moral and social qualities). Physical condition and home conditions were also taken into consideration. The children were tested individually for intelligence, using a modification of the Stanford Revision of the Binet-Simon Scale.

As a result of the experiment, the type of employment considered most suitable for each child was suggested. In some cases the advice of the investigators was followed, in others not. For a period of two years the after-careers of the children were carefully observed from time to time in order to discover the success or otherwise of the children in their employment. The following statement was made at the conclusion of the experiment:—

‘The outcome of the inquiry speaks strongly in favour of the methods

used. The scheme has proved workable, the results unexpectedly successful. Of those who entered occupations of the kind recommended, over 80 per cent. are satisfied with their work, their prospects and their pay. Of those who obtained employment different from the kind advised, more than 60 per cent. are dissatisfied, and most of those who are satisfied appear to be so because they have exceptionally good employers rather than because they like the work. Further, judged by the after-histories of the several children, those who accepted the advice given have proved more efficient and successful in their work than those who rejected the advice. They are, on the average, in receipt of higher pay; they have generally obtained promotion earlier, and have experienced fewer changes of situation.'

A second experiment is now being carried on by the Institute on a far more extensive scale. Six hundred children are being examined and advised, and their subsequent careers will be compared with those of a 'control' group of an equal number of children to whom the Institute's advice has not been given.

A generous grant from the Carnegie United Kingdom Trust has made this second experiment possible.

The following statement indicates the present position :

'The Experiment carried out by the National Institute of Industrial Psychology in London into the possibility of using psychological tests in Vocational Guidance is one of considerable interest and importance. The number of young people studied (six hundred) was large enough to enable statistical methods to be applied to the analysis of the data collected. Moreover, the use of a control group (also six hundred in number) made it possible to assess more exactly the value of the vocational guidance offered. The main aim of the experiment was to establish a practical procedure of vocational guidance for children at school leaving age (i.e. 14).'

'Information was sought relating to the child's school record and to his hobbies and out of school life. This was supplemented by data obtained from psychological tests of various kinds. Among the latter may be mentioned tests designed to measure general intelligence, ability in the use of language, ability in dealing with practical situations, ability in handling machines, in manipulative activities, in computation, in the perception of shapes and forms and the like. During the years that have elapsed since the children who were advised left school, close touch has been maintained with them and much information relating to their occupations and changes of work has been collected. So far as it has been analysed up to the present the results are very encouraging. Those boys and girls who have found work of a kind similar to that recommended have changed their employment less frequently than those who have entered work unlike that recommended to them. These later results confirm those obtained in an earlier experiment carried out by the Industrial Fatigue Research Board and the National Institute of Industrial Psychology.'

This important confirmation of the earlier experiment is of great value. In the light of these investigations it is not unreasonable to hope that, in days to come, every boy (and girl) on leaving school will have reliable information as to the kind of work in which he can most effectively use the ability he possesses, with pleasure and satisfaction to himself and to

his employer. In this case the hopeless situation involved in 'the square peg in the round hole' will tend to disappear.

For many years it has been recognised that there has been a considerable amount of 'marking time' in elementary schools, from 11 to 14 years of age. There has also been a strong feeling that adequate opportunity has not been given to boys and girls to express themselves in practical activities, and that for a large proportion of the children the purely academic nature of the curriculum was profoundly unsatisfactory. The Hadow Report emphasised this very unsatisfactory state of affairs in various departments of educational procedure, and recommended drastic changes in many directions.

The result has been a decision of the Board of Education to bring about a thorough re-organisation of the Schools. The scheme is admirably described in the Board's Educational pamphlet (No. 60) bearing the title 'The New Prospect in Education.' It would be difficult to over-estimate the importance of this pronouncement which is veritably a message of glad tidings for the children, who will derive enormous benefit from the more generous outlook on education, and the ampler provision of facilities for practical and more interesting work. It marks the first stage in the forward movement towards 'secondary education for all.'

Based upon the famous Hadow Report, the pamphlet gives official sanction and encouragement to schemes for which pioneers in education have been fighting and pleading for many years. It sounds the death-knell of any number of abuses which have had a strangle-hold on the free development of a vigorous personality by the less intelligent children of our schools. Not only that, the important reforms which are proposed are conceded in no carping spirit, but with a generous outlook which does infinite credit to a great Government Department. The various points are set forth with a definiteness which admits of no misunderstanding; there can be no going back.

The most important conclusions are the following :

(1) That primary education should be regarded as ending at about the age of 11, and that all children should then go forward to some form of post-primary education.

(2) That this second stage should as far as possible be organised as a single whole within which there should be variety of types.

The varieties of post-primary schools in large centres of population will be : (1) The ordinary senior school under a new head teacher with a change of curriculum and greater facilities for practical work. (2) The junior technical school with a direct leaning to a particular trade or group of trades. (3) The central school with a definite bias towards industry or commerce. (4) The secondary school with a higher standard of education for children who may remain under instruction up to the age of seventeen or eighteen years.

In most districts, the scholarship competitions at eleven years of age will, to a large extent, settle the transfer to secondary and central schools. Children who are so fortunate as to gain admission to these senior schools, with or without money grants in addition to free education, are generally those of superior mental ability and they should do well in after life. In the secondary school different courses are open to them, some leading to a

university career, others to professional life, or to good positions in industry or commerce. In the secondary, central, and junior technical schools the break from the primary school is complete.

Clearly, the most difficult problem in this important scheme of re-organisation is the ordinary senior school, which a large proportion of the children will attend. The stimulus of a new environment is of peculiar value at the age at which the transfer comes. With a new headmaster, a separate entity, a group of children within a narrower range of age, good practical workrooms, and a large number of fresh interests may produce that change of atmosphere which is necessary for complete success.

Much thought and wisdom will be needed from those in authority in deciding as to the best kind of senior school for each child. An intimate knowledge of the boy or girl, the personal equation, the direction indicated by the child's interest, the possession of any special ability and so on, are necessary for a decision on which so much depends for the future welfare of the scholar.

In dealing with modern movements in education it is necessary to make a passing reference to the great possibilities offered by the cinema and the wireless. Experiments in various directions, as we shall see, have been, and are still being made to explore methods which may result in one, or, still better, both, playing a useful part in modern schemes of education. The natural objections raised to purely visual or purely auditory instruments in educational procedure may be met within the near future by the speaking film or the synchronisation of the normal educational film with the loud-speaker, thus eliminating the obvious necessity of the film lecturer.

The comparative failure of the so-called educational film in picture houses is largely due to the attempt to satisfy the student, and at the same time secure the interest of the larger *clientèle* of the picture palace, the popular audience, which is rendered necessary for financial reasons. During the sitting of the Cinema Commission an investigation was made of the popularity of different types of film among the school children frequenting picture palaces. In practically every case the educational film was at the bottom of the list. It did not appear possible to meet the claims of the two classes of patrons, although praiseworthy attempts were made to produce exceptionally good results from the point of view of successful production. For educational purposes it is evident that the element of popular appeal must be subordinate to the instructional objective.

On the other hand, a valuable research has been carried out, aided by generous subventions by the Carnegie Trust and the National Council of Public Morals, to test the efficacy of the moving picture (film) as compared with the static picture (lantern slide) for teaching purposes. Prof. Spearman accepted the chairmanship of the committee appointed, and his psychological laboratory at University College, London, was fitted up with cinema appliances for the conduct of the investigation. Groups of children from neighbouring schools were instructed in different subjects by means of the lantern and the film respectively. The result was that there appeared to be an advantage of about 20 per cent. for the moving picture both for immediate and delayed memory tests.

Many schools have recently experimented in using broadcasted material as part of the general scheme of instruction with considerable success, any initial difficulties having been successfully overcome. It is probable that, in the days to come, the employment of the means of instruction offered by the cinema and broadcasting, either separately or together, will exercise increasingly useful functions in educational processes.

During the very fertile period of advance through which we have passed since our meeting here in 1905 many valuable movements in education have come upon the scene. I have only been able to touch very lightly and imperfectly on a few of the more important of those which have broadened our outlook and have materially increased our interest. I have found it very difficult in this brief survey to break away from the absorbing interest one feels in the claims of the young child for special attention. My investigations of such interesting subjects as the sense of humour and the dreams of English and American children have possibly given me an exaggerated estimate of the importance, and of the extraordinary delight, of the study of early child life.

Had time permitted I should like to have dwelt for a short time upon the remarkable progress made in recent years in the organisation of adult education in connection with the University Extension Movement and the beneficent activities of the Workers' Educational Association. But I have already gone beyond the normal time limit for a presidential address, and I must ask you to forgive the many sins of omission and commission.

SECTION M.—AGRICULTURE.

AGRICULTURE AND THE EMPIRE.

ADDRESS BY

SIR ROBERT B. GREIG, M.C., LL.D., M.Sc.

PRESIDENT OF THE SECTION.

IN this country, which Kipling has described as 'the last and the largest Empire, the map that is half unrolled,' a Pan-African Congress of Agriculture is meeting side by side with the Agriculture Section of the British Association, which is an Imperial Body for the advancement of science.

The Imperial aspect of Agriculture is surely therefore a subject for consideration and discussion.

Membership of an Empire such as ours is, like freedom, a noble thing. The mere size of the Empire grips the mind and makes an emotional appeal which, when fully realised, is a step towards a unified world. The Empire is so widespread and so various that it can accommodate every kind of mind or body. A man feeling cramped in Scotland can find room in South Africa. He who finds his intellectual horizon limited in New Zealand may find his spiritual home in Oxford or in Edinburgh. Because the Empire includes so many diverse peoples differing in physical and mental attributes, and because it yields such a variety of natural products, it offers problems political, social, and industrial, of peculiar interest and complexity. It can provide greater facilities than can small homogeneous units, for within the Empire is every kind of external stimulus that goes to promote mental development and intellectual advancement.

Moreover, its political structure is of peculiar advantage. The free nations of the Commonwealth, along with the great non-self-governing territories, can meet without difficulty or embarrassment for the discussion of common problems. They have a focal point or centre in England from which concerted action may, if desired, be taken. When action is taken they have the largest outdoor laboratory in the world; a field for action which allows in some part or parts the investigation of problems of almost every description.

But citizenship of the Empire involves responsibilities. The principle of trusteeship is admitted. The governments are trustees for rich territories covering nearly a quarter of the globe. They are also responsible for hundreds of millions of native populations. These native populations can rise in the scale of civilisation only according as they may be influenced by education, sanitation, law and order. But these influences can be exerted only in proportion to the prosperity of agriculture and industry. In our colonial Empire in the past we have concentrated chiefly upon administration, and we have reason to be proud of the results. But the native populations will judge us in the future not by the excellence of our administration but by the means we take to help them to a higher standard

of living and to secure for them some of the benefits of civilisation. We, then, as citizens, are bound to develop the Empire even for the sake only of the native populations. Finally, we are trustees to the world in general as custodians of so great a part of the world's wealth.

The progress of civilisation depends upon science, not science stated crudely as chemistry or botany, but the scientific spirit applied to all aspects of life. If science is applied to the economics of the Empire, the greatest economic asset to which it can be applied is agriculture. From the standpoint of area, or wealth, or population employed, agriculture is by far the most important activity in the Empire. The true wealth of the world, the wealth which determines the standard of living of nations, is limited by the capacity to produce cereals, milk, meat, wool, cotton, hides, and other prime necessities of life of soil origin; without a sufficient supply of these progress in the art of living is impossible. Agriculture is also the one stable industry. Coal seams come to an end, or the discovery of new sources of energy changes the values of coal. Advances in physical science may, while creating new industries, destroy old ones. The wealth of gold and diamond fields depends upon artificial values which might disappear if society were constituted on a new basis with a different monetary system and different culture. But agricultural wealth, the capacity to produce every year the food and clothing without which life ends, is and always has been the one great permanent industry, the one which is the foundation of all national or indeed of world wealth.

THE EXTENT OF EMPIRE AGRICULTURE.

The British Dominions, India and the Colonies cover 24 per cent., or nearly one-quarter of the globe, and they contain 24 per cent., or nearly one-quarter of the world's population.

Of this immense area no precise measure of the full extent of land in agricultural use is available, but the proportion is small. The most intensively cultivated of the larger areas is India, the least intensively cultivated is Australia. (See Table I.) In the aggregate only 8·7 per cent. of the total land surface of Canada, India, the Union of South Africa, Australia, and New Zealand is under arable cultivation. Only about one acre in every hundred of Australia is under cultivated crops, about two and a half acres in Canada, and three acres in South Africa and New Zealand respectively. It is difficult to obtain figures indicative of the possibilities of the tropical and sub-tropical territories, but the African possessions alone are capable of enormously increased production.

In the nine provinces of Canada the 'possible farmland' is 358 million acres, or about one-quarter of the total land area of the provinces, and five and a half times the present total of both arable and pasture. In India, the most intensively cultivated, it is estimated that the cultivable waste land is equal to half the present cultivated area, or about 153 million acres.

Some evidence of the importance of the grasslands of the Empire is obtainable from the numbers of the world's live stock. (See Table II.) Of every hundred head of cattle in the world, forty-four graze on Empire pastures, and of every hundred sheep, thirty-eight are in the Empire. Australia and New Zealand together own approximately as many sheep

as the whole of Europe, excluding the United States of Soviet Republics. Evidence of what the Empire might do in grassland products is provided by the figures of imports of live stock products into Great Britain. The British market imports £330,000,000 worth of grassland products annually, which is about one-quarter of the imported goods of all descriptions. Of these foodstuffs which come from the grass, one-half, or about £160,000,000, come from the Empire.

It is easy to realise the importance of agriculture in Canada or Australia, but in an industrial and mineral country such as Great Britain, and in a great mineral-producing country such as South Africa, the place of agriculture is apt to be overlooked. (See Table III.) In the three larger Dominions and even in Great Britain, agricultural production is more valuable than mineral production. It may be astonishing to some to learn that Great Britain, including Northern Ireland, produces more agricultural wealth than Australia and four times as much as South Africa. When the value of minerals is combined with the value of manufactures, even then the agriculture of Canada and Australia is more important than minerals and manufactures combined. The dependence upon agriculture for the prosperity of the overseas trade of some of these countries is striking. (See Tables IV and V.) Of New Zealand's produce exports, for example, 89 per cent. are agricultural and only 11 per cent. non-agricultural. The produce exports of Australia show 84 per cent. to be agricultural; while from South Africa, only 31 per cent. are agricultural, and from Great Britain less than 3 per cent.

The distribution of the population dependent upon agriculture is best shown by such countries as South Africa, India, and Nigeria. In South Africa, in spite of its small agricultural and great mineral production, 37 per cent. of the population are engaged in agriculture and only 5 per cent. in mining. In India 72 per cent. are dependent upon agriculture and in Nigeria (which is three times the size of Great Britain, and one-third of the size of British India), practically the whole population depends on agriculture.

It is obvious that a vast area of the Empire is capable of further production, even if developed only on the present lines with the application of existing knowledge. But if we apply not only the science now at our disposal but the results of further researches and investigations which are sure to follow, the potentialities become almost incredible.

RELATION OF SCIENCE TO AGRICULTURE.

Let us come now to the relation of science to agriculture. Agriculture can be regarded as the application of all the sciences to the exploitation of the soil. There is scarcely a branch of pure science which may not contribute some knowledge which agriculture can apply. But agriculture differs from other industries in which a new discovery may be followed by a sudden transformation in methods. Agriculture is old, slow-moving, and conservative. The life cycle of animals runs into years, and even in cropping a rotation of years must often be followed to get the full effects of any change of method. Hence, the results of research are absorbed slowly and almost imperceptibly into farming practice. Nevertheless, there have been numerous instances when the advance has been so rapid

that the farmers applying the knowledge have been within sight of the source of the knowledge.

The case of 'Marquis Wheat' is well known. This wheat, bred by the Canadian Experimental Station at Ottawa, has by its earlier maturity and superior cropping powers, not only ousted the older and inferior varieties of wheat in millions of acres of Canada and the Northern United States, but it has made the cultivation of wheat possible in areas where wheat could not be grown before.

A variety of sugar cane has recently been produced in Java by the Dutch Plant Breeders; one of its ancestors was not a sugar cane at all but a wild reed growing in a marsh. Yet this variety partly of reed ancestry is greatly superior to any other, giving 15 per cent. to 20 per cent. more sugar and resisting local diseases better than any other. Most of the sugar fields of Java are now growing it. The sugar production of Java since 1840 shows the following increase and offers one of the finest examples of the effects of the application of science to plant breeding, manuring, and cultivation. (Five-year periods—average for each five years).

1840-45	.	.	.	.	.	24 piculs per bouw
1865-70	.	.	.	.	.	50 " "
1900-05	.	.	.	.	.	100 " "
1920	.	.	.	.	.	120 " "
1925	.	.	.	.	.	132 " "
1928	.	.	.	.	.	150 " "

Comment is superfluous.

The grasslands of the Empire, as I have shown, support at least 500,000,000 animals. If all these animals were suited to their environment, free from disease and sterility, and sufficiently nourished, their value would be far more than doubled or trebled. South Africa, through Sir Arnold Theiler and his staff, has already demonstrated to the full part of this possibility. In discovering the cause of and the means of combating certain insect-borne diseases, Sir Arnold and his associates have saved the Union millions of pounds. Equally spectacular is the biological control of noxious weeds, such as the prickly pear in Australia and the blackberry in New Zealand. In the field of animal nutrition, it has been discovered that diseases may be caused in farm stock by the absence of minute quantities of iodine, lime, phosphorus, or vitamins. The cure of rickets in pigs, and styfsiekte and lambsiekte in cattle, by the administration of bone meal and salt and other mineral mixtures has already saved hundreds of thousands of pounds to stock farmers. The application of the newer conception of the balanced ration, which we now have as the result of the studies of physiologists and biochemists, is yielding its return in increased production.

The intensive management of grassland in such great grazing countries as Australia, New Zealand, and Great Britain is only beginning, but already it is plain that production can be doubled under skilful management. Even the fertiliser or artificial manure, concerning which we know more than of almost any other agricultural improvement, has far wider fields to conquer than any which it has yet subdued.

These great achievements give us the assurance that the application of pure science to agriculture will yield results of a value many times greater than the money expended.

THE EMPIRE AS AN ORGANISM.

If my figures and arguments are accepted, the British Empire must be regarded as an amazing organism. Is this organism developing symmetrically, and is it desirable to take thought as to its development? It may be argued that no great thought is needed, that each part of the Empire left unfettered in the pursuit of well-being in its own way, will eventually provide the best conditions for its inhabitants. But this argument totters in face of the Canadian Wheat Pool, which sooner or later will compel the wheat-growing parts of the Empire to consider their ways and to come to an arrangement whereby the Empire wheat comes under some uniform system of organised production and orderly marketing. The argument is further confuted by the fact that South Africa has joined with Australia and New Zealand in a great co-operative marketing and purchasing agency in London, known as Overseas Farmers' Co-operative Federations, Ltd. These straws show the way the wind blows, and makes it unnecessary to labour the point, for few will hold that nothing is to be gained by co-operation in effort. If that be so, the question that occurs to me as an official concerned with agricultural development is, what share, and it must be a very large share, can research applied to agriculture take in the proper growth and nurture of the organism?

In the first place, it is clear that there are large economic problems affecting all parts of the Empire which await solution if the Empire is to be properly developed. There is, for instance, sterility and abortion in live stock. There is the pasture problem. There are insect-borne diseases. It is almost hopeless for a single individual or even a single institution to attempt the solution of any of these great problems. Each problem has so many aspects that team work is needed in the widest sense—not only between individuals, but between institutions and between governments.

In the case of sterility and abortion in cows, for instance, there is here first a problem for the bacteriologist and the pathologist, as the micro-organism which causes contagious abortion is probably the most important factor. There is a nutritional factor, as it is well known that deficiencies in the diet cause both sterility and abortion, and may also render the animal more susceptible to the invasion of the organism. Moreover, in this as in other diseases, there is a problem for the geneticist, to discover to what extent, if any, is the tendency inherited, and what may be the correlated factors which indicate the susceptibles and the highly resistant strains. Finally, if or when the knowledge arrives which makes possible the elimination of the disease, the co-operation of the administrator is required to frame and execute the regulations recommended by the scientists.

The most recent development of the work on pastures has been in connection with their chemical composition. It has been shown that chemical composition, if it takes account of all known food constituents, is an indication of the feeding value of pastures, and it has been proved independently in various parts of the world that deficiencies of one or other nutrients required only in small amounts, are the cause of definite diseases. Further, it has been shown that if these deficiencies are made good, not only are the diseases prevented, but production is increased, and there is reason to believe that susceptibility to disease generally is decreased, and what is also of great economic importance,

animals breed true instead of undergoing the well-known deterioration which takes place in improved breeds when put upon poor pastures. The better exploitation of the pastures of the Empire is a problem which requires, for a complete investigation, the pathologist and bacteriologist to deal with the diseases which occur in deficient areas; the physiologist and biochemist to deal with the composition of the pasture and to determine to what extent it meets the requirements of the grazing animal. There is needed also the work of the plant breeder and the soil chemist for the improvement of the pasture as a crop.

To bring about a concerted and co-operative attack upon such problems as these a certain procedure seems desirable, but before suggesting that procedure, let me point out that the facilities for co-operation are now immeasurably greater than they were even thirty years ago. Rome fell from various causes, but no doubt one of its defects was the absence of newspapers and telegrams by which the outlying parts of the Empire might have been kept in communication in time to avoid or avert some of its disasters. We have no such excuse. Communication is easy, transport is easy, conference is easy. In many ways Pretoria and London, and Ottawa and London are nearer to each other to-day than London and Edinburgh were 150 years ago. Moreover, a foundation for action exists which did not exist in the nineteenth century. In many parts of the Empire and especially in the self-governing Dominions, research has been going on in agriculture for a generation or more, and a great body of knowledge has been built up, much of which can be applied.

THE PROCEDURE FOR EMPIRE RESEARCH.

Provided, then, that we have a large enough conception of Empire development by research, the procedure should be:

- (a) to outline the problem;
- (b) to collect all available information concerning it;
- (c) to make a plan of campaign;
- (d) to find the money to finance the research;
- (e) to find the men to do the work.

To carry out this procedure it so happens that we are in a more favourable position than ever before in the history of the Empire. The urgent problems that arose during the war demanded a solution on immediately practical lines. Tremendous advances were made in some of the applied physical sciences, as a result of the fact that all scientists who could contribute to the solution of an urgent problem were brought together and urged to work in such a way that their energies were focussed on a known objective. Following on this war experience, a similar spirit of co-operation has been developed in agricultural science. It is interesting to trace how this spirit has been stimulated and encouraged.

In 1925 the British Government set up an Imperial Economic Committee, with an annual grant of £1,000,000, for the purpose of encouraging trade in Empire products in the United Kingdom. The Imperial Economic Committee recommended that the annual grant should be used, first, to create in the United Kingdom a voluntary preference for Empire goods, and, second, upon research to improve the quality and supply of Empire

goods for sale in the United Kingdom. The British Government, after consultation with the Dominion Governments, accepted the Report and created the Empire Marketing Board, which is the executive body for the administration of the funds. The Empire Marketing Board early turned its attention to the encouragement of research as the second of its functions.

Almost simultaneously with the creation of the Empire Marketing Board was set up the Committee of Civil Research, consisting of the Prime Minister and the Lord President of the Council, with power to set up *ad hoc* sub-committees for any purpose other than military. Here, then, we have already two bodies calculated to assist in the procedure which I have outlined. The Committee of Civil Research, flexible enough to inquire into and report upon any non-military subject under the sun, and the Empire Marketing Board—a body with funds to finance research.

It was borne in upon those who had inquired into research in the non-self-governing Colonies that much good work was lost in pigeon holes, that scientists were sometimes engaged on the same problems unknown to each other, that overlapping occurred, and that facilities for the exchange of information were inadequate. Accordingly, when the Imperial Agricultural Research Conference was held in London in 1927, influenced as it was by the great success which had followed the formation of the Bureaux of Entomology and of Mycology, it strongly recommended the creation of clearing stations or Information Bureaux for the collection and distribution of information concerning certain sections of agricultural research. The proposal found acceptance with the British and Dominion Governments and with the Colonies, and several of these bureaux are now in operation. I believe that they will prove of extraordinary value in the development of the Empire. They are eight in number for the present. How far they may be added to, experience will decide. They are all, by the unanimous decision of Empire delegates, situated in Britain. They deal with Soils, Animal Nutrition, Animal Genetics, Animal Hygiene, Plant Breeding, Animal Parasitology, and Fruit Production. They are not research institutions, but in each case they are attached to research institutions, and their first directors are the directors of the research stations.

Each bureau will focus the information on the subject—will act as a gathering ground for theories and theorists, as an illuminant and expositor, and eventually we may hope, as a finger-post to new and profitable roads and by-paths of research. These bureaux, to which all Governments of the Empire have agreed to contribute, embody the first organisation which is Imperially owned and Imperially governed, and which has been set up to serve the Empire.

The Bureau of Soils at Rothamsted, or of Animal Genetics at Edinburgh, is just as much the property of South Africa and Australia as of England or Scotland; and England and Scotland sit on the Executive Council as representatives only of their countries.

It is not enough, however, to accumulate details. It is foolish to make a list of the stars and remain content with the catalogue. The details must be followed by a synthesis to sum up and explain the details, and arising out of the synthesis will appear the clues to some problems, the explanation of others, and the broad lines of strategy on which the

research battalions should move. Each Dominion or Colony has its own problems peculiar to its conditions, but the fundamentals of science are everywhere the same.

In addition to the researcher, it is then necessary to have other types of scientific workers. The research worker is properly and sufficiently engrossed by his speciality. He seldom has time for or interest in the wider conceptions. His point of view is generally limited by his subject. But the application of science is not confined to the research worker. The broad results of research can be understood by politicians who can set the wheels in motion through their Governments. Scientific men are wanted who can see the wood without the trees, who can see the possible bearing of unconnected facts, and who can use their imagination at long range. Such men, if they use the scientific method, are as truly scientific as the researcher himself.

We have then machinery to deal with three of the five necessities for Empire Research. We have the bureaux to collect information. We have the Committee of Civil Research to consider the information and plan a campaign, and we have the Empire Marketing Board to provide the funds. There remain to be considered the men, and the origin of the problem.

As to the men, the great Dominions can and will provide and train their own men. The success of South Africa in the production of research workers whose reputation is world wide is sufficient evidence of what the Dominions can do. The case is different in the Colonies. As a rule, the research workers in the Colonies must be recruited from Home or Dominion sources and partly trained outside of the Colonies which they serve. Much has been written concerning the need for these workers, their status, pay, and pension. It is enough to say that the development of the tropical and sub-tropical possessions depends upon making the career of a colonial research worker as satisfactory as the alternative, less interesting, and perhaps more sordid business of making a living. There is one aspect of the man power that must not be lost sight of in considering Empire research, and that is the desirability of exchange of workers. Nothing can be more profitable and stimulating in suitable circumstances than change of environment to the research worker. He obtains a new lease of scientific life, a wider outlook, a wealth of experience of men and methods denied to him as a limpet in an institution. There are difficulties in the way of exchanging workers on any considerable scale, but these difficulties will decrease as time passes and the temporary exchange of work and of workers will prove of far-reaching benefit.

THE PROBLEM.

I come now to the Alpha and Omega of research—the beginning and the end—‘The Problem.’ It might be assumed from some of the foregoing remarks that, like many an administrator before me, I have been erecting a rigid structure into which I propose to fit a flexible and incalculable body. Far from it: wide experience shows that the feet of research cannot be crammed into the shoes of regulations. One knows where the shoe pinches.

The facilities I have described arise from the recognition of the value

of co-operation in research by Governments, and from the desire for co-operation in research on the part of the workers. The structure is an arrangement for the assistance of research, not a frame in which to fit it.

The problem which these organisations have been created to help to solve may arise in various ways. It would be easy to mention many outstanding Imperial problems, but assuming that some individual research worker in some corner of the Empire has seen or shed new light on some obscure point, what is his happy condition to-day compared with twenty years ago? Through the bureaux or clearing centres of information, he can mobilise all the existing knowledge bearing on his point. Armed with this knowledge, he sees that the scope of the required research is far beyond his individual powers. If he is in one of the Dominions he can put his case before the Department of Agriculture or, it may be, before the Department of Scientific and Industrial Research of his Government. The Department can bring together the best brains available to consider and report upon the necessary research, or in the case of Great Britain and the Colonies, the Committee of Civil Research can undertake the inquiry. A plan of campaign is ultimately worked out. The Empire Marketing Board is approached and the funds jointly provided by the Board and the Dominion or Colony chiefly concerned. The men are then selected, possibly from the whole Empire, and seconded for the work, the locus is decided upon and the attack begins. In this case the problem has originated through the vision of one individual.

Take another case, where the problem originates at the other end of the scale. Take a simple illustration. Suppose, and this is probably true, that the sheep on the hill grazings of Scotland and England have diminished by one-third in fifty years. The Agricultural Administrator concerned appeals to the Research Institutes. They reply that there are probably half a dozen factors contributing to the decrease. Then follows the inquiry, the suggested plan of campaign, the funds, the men, and the attack. Yet out of such an investigation may arise the information which will enable principles of general application to be determined regarding sheep and pastures over half the world. Here the administrator has set the ball a-rolling.

But the politician, or to give him a worthier name, the Statesman, is not out of the swim. Let us suppose that South Africa wishes to take a large share in the supply of chilled beef and mutton to the great industrial centres of England. Immediately there arises a problem economical, genetical, nutritional, pathological and botanical, which can only be solved by the combined operations of a number of scientific and business men working together.

Finally, there is another way in which the problems may arise. That is through the deliberations of a long range thinking body not concerned with the problems of to-day or even the immediate to-morrow, but with research which has no present relation to agricultural practice but which may prove a fertile source of lines of investigation ultimately of the first importance to agriculture.

We have then available organisations or machinery capable of doing great things for the development of the Empire. Already much has been

achieved. The Empire Marketing Board in two and a half years has made grants up to the end of 1928 aggregating a million and a half. The spread of these grants as seen from the map and table are interesting. A fine example of what has already been done in Imperial team work is offered by the Grassland Research.

The headquarters of this research is in Aberdeen and the Chief of Staff is Dr. Orr. Under his direction, teams have been investigating the mineral deficiencies of pastures in Kenya, in the Falkland Islands, in Palestine and in Scotland and England. Arising out of these investigations and those of Sir Arnold Theiler, similar campaigns have been started in Australia and New Zealand. Here, in the space of only two or three years, we have through vision and staff work an Imperial Investigation which promises to increase enormously the output of beef and mutton from Imperial grasslands.

As a result of these pasture researches the workers engaged have been in consultation with each other and a spontaneous tendency to co-operation is bearing fruit. In consequence, the pioneer work of Onderstepoort is known and appreciated in Great Britain and elsewhere and is being applied successfully. The work of Aston in New Zealand on 'Bush sickness' is being applied in East Africa. The Canadian work on the prevention of goitre in grazing animals is a stimulus to work in other countries such as Australia and New Zealand where there is believed to be a deficiency of iodine in the pastures. If similar developments can take place in other lines of research there is a possibility of great advances during the lifetime of the present generation.

I hope I have said enough to show that the application of science and commonsense to the development of the Empire, and particularly of its agriculture, promises rich rewards.

NEW ADJUSTMENTS.

As it seems probable that great adjustments will need to be made in methods of agriculture, and in the organisation of supplies, it seems essential that while we have the time we should think Imperially and think ahead. The International Economic Congress at Geneva in 1927 diagnosed the depressed condition of European agriculture as being due to unremunerative prices. The Congress negatived the conclusion that the fall in prices was due to any excess of production. It was, on the contrary, of opinion that, relatively to the growth of population, there has been no increase in output over that of 1913. With this opinion Sir Daniel Hall, as shown by his address at Oxford in 1926, would agree.

Lord Ernle, the Minister of Agriculture during the war, said recently: 'The question has already arisen how far it is safe in the world's interests to allow the decline of agriculture. Workers once attracted to the towns never return. Inevitably, in course of time, whether sooner or later it is impossible to predict, nations will be feverishly striving to rehabilitate agriculture under the overmastering influence of food shortage.'

This opinion of Lord Ernle's may be somewhat pessimistic, but local famines do occur. In Kenya there was a partial famine this year. Famines are recurrent in India, and many thousand people in Ireland died of famine less than a hundred years ago.

On the other hand, we have Mr. Speyer stating in *Nature*, January 12, 1929, with reference to the manufacture of nitrogen fertilisers from the air, that if the nitrogen supply which is in prospect by 1931 were applied to the main crops of Europe at the rate of .8 cwt. per acre, the population at that date would not consume more than half of the extra food which would thus be available. We have also Professor Stewart, formerly of the Minnesota Agricultural College, asserting that since 1850 machine farming developments have released approximately twenty-seven million workers from agriculture. He also states that with two-horse machinery forty hours of labour were required to grow a crop of maize, but now with modern machinery less than four hours of man labour per acre are required.

Whatever may be the significance of these opinions or the ultimate value of these statements, one thing certain is that the development of the agricultural resources of the Empire is of the first importance.

THE OPPORTUNITY.

We have the only system of government in the world that can link up research in countries with all kinds of soils and climates. We have the finest and most varied laboratory in the world. We have the nucleus of an organisation and we have the opportunity.

Within the Empire is the Empire's greatest market for agricultural produce and the Empire's greatest source of supply. The development of agriculture would have an enormous influence in the development of Empire trade. Co-operation in research leads to better understanding between the Dominions, the Colonies, and the Mother Country. Conferences of research workers and administrators lead to the discovery of common aims and ideals, as was shown in the Conference of 1927, and the pursuit of common aims is one of the most enduring of ties. But the scientific man knows no boundaries; he is one of the few real internationalists in the world to-day; the knowledge he obtains is subject to no tariff, receives no bounty, is freely exchangeable throughout the world. As a scientific man—if he is within the British Empire—he may engage in the solution of larger problems than probably any other unit can provide.

And what may be the end of his research? One may speculate, but the end should surely include an orderliness, a co-ordination of parts, and a relationship of functions which should make for greater prosperity and for greater stability and freedom from temporary over- or under-production of agricultural commodities. It is not suggested that the exchange of commodities should be intra-imperial. Even if that were desirable it is not possible. The trade of the Empire is shared almost equally between the Dominions and foreign countries. (See Table VI.) It is not that the Empire may be a self-contained and self-supporting quarter of the globe that I make these suggestions. To succeed in such an aim would be to end nowhere or to end in destruction. I make these suggestions because the nations which make up the British Empire form a political body which faces an opportunity open to no other system of governments in the world. This opportunity is the possibility that by taking thought and by organising the acquisition and the application of knowledge, the wealth of the Empire can be greatly increased, and thereby, and necessarily, the wealth of the rest of the world will be increased also. It is a far cry to an organised

Empire, but if the object is worth it, the initial step is to adopt the 'view-point' described by General Smuts. With the view-point and the mental field surrounding it come the creative ideas which in the end realise the dream. What I plead for, then, is the 'view-point.' Even in the prosaic occupation of agriculture, of the earth earthy, I suggest that the Imperial view-point is stimulating and creative.

The conception of an organised agriculture based upon science should, I think, be part of the mental equipment of every statesman and administrator. The same vision should inspire every research worker if, in the words of the late Lord Morley, he is to weave the strands of knowledge into the web of social progress.

If the vision is keen enough, the conception wide enough, the energy enduring, and the courage unflinching, is it not possible that the group of free nations which constitute the British Empire may demonstrate the means and lead the way to that wider world government to which every generous and contemplative mind would look?

TABLE I.

Land returned as arable in the following countries.

Country.	1000 acres.	Percentage of Total Area.
Great Britain	13,500	24.0
Northern Ireland	1,180	35.6
Irish Free State	3,640	21.7
Canada	56,400	2.4
India (British)	300,000	45.8
(Native States)	80,000	59.1
Union of South Africa	9,400	3.1
Australia	22,500	1.2
New Zealand	2,000	3.0

TABLE II.

Live Stock of the Empire.

—	World Total (1927) omitting China and a few other areas.	Empire Total (1925) in- cluding Great Britain and Mandated Territories.	Percentage of World Total.
Horses .	102,000,000	11,000,000	11
Cattle .	560,000,000	245,000,000	44
Sheep .	650,000,000	245,000,000	38
Pigs .	205,000,000	11,000,000	5

Sources of Information.

'International Yearbook of Agricultural Statistics, 1927-28.'

'Statistical Abstract for the British Overseas Dominions and Protectorates (Cmd. 3198), 1928.'

'Agricultural Statistics of the Ministry of Agriculture and Fisheries and of the Board of Agriculture for Scotland.'

TABLE III.

Ratio of Agricultural and Industrial Production.

	Agricultural Production.	Mineral Production.	Value added by Manufacture.	Ratio of A to B plus C.
	A.	B.	C.	
	Millions of £'s.			
Australia (1925-26) .	250	24½	143	1 : 0·675
Canada (1926) .	342	49½	280	1 : 0·96
Union of South Africa (1923-24) .	67	55½	40½	1 : 1·43
Great Britain (1924-25) .	274	230	1376	1 : 5·9

Sources of Information.

‘Statesman’s Yearbook, 1928.’

‘Canada Yearbook, 1926.’

‘Yearbook of The Union of South Africa, 1926-27.’

‘Agricultural Output of England and Wales, 1925 (Cmd. 2815).’

‘Agricultural Output of Scotland, 1925 (Cmd. 3191).’

TABLE IV.

Extent to which agricultural output of the Empire is absorbed by the population of the producing countries.

	Agricultural Production.	Value of Agricultural Exports.	Exports as percentages of Total Production.
	Millions of £'s.		
Australia (1925-26) .	250	134	54
Canada (1925-26) .	342	136	40
Union of South Africa (1923-24) .	67	24	36
Great Britain (1924-25) .	274	18·6	6·8

Sources of Information.

As for Table III, and ‘Statistical Abstract for the British Overseas Dominions and Protectorates (Cmd. 3198), 1928.’

TABLE V.
Ratio of Agricultural to non-Agricultural exports.

	Agricultural Exports.	Total of all articles of domestic produce exported.	Percentage of Agricultural Exports to Total Exports.	Ratio.	
				Agri-cultural.	Non-Agri-cultural.
	Millions of £'s.				
New Zealand (1925) .	48·6	54·5	89	8·1	1
Australia (1925) .	134	159	84	5·25	1
Irish Free State (1925)	30·1	43·4	70	2·3	1
Canada (1926) . . .	133·5	279·8	48	0·9	1
Union of South Africa (1925)	26·3	84·5	31	0·45	1
British India (1926) .	147·8	250·7	58	1·4	1
British Malaya (1925)	87 (Rubber only)	150	56	1·3	1
Great Britain and Northern Ireland .	18·6 *	653	2·8	0·03	1

* Exports of home-produced and of re-exported produce are not clearly distinguished.

Sources of Information.

'Statistical Abstract for the British Overseas Dominions and Protectorates (Cmd. 3198), 1928.'

'Annual Statement of Trade of the United Kingdom, 1927.'

TABLE VI.
DISTRIBUTION OF EXPORTS OF THE DOMINIONS AND COLONIES.
Millions of £'s

Exported from Empire Countries to

(a) Empire Countries.

(1) United Kingdom	433·7	
(2) Overseas Dominions	141·0	(48½ per cent.)

(b) Foreign Countries	607·6	(51½ per cent.)
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Total Exports to the World	<u>1182·3</u>
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DISTRIBUTION OF IMPORTS OF THE DOMINIONS AND COLONIES.
Millions of £'s

Imported into Empire Countries from

(a) Empire Countries.

(1) United Kingdom	374·7	
(2) Overseas Dominions	147·6	(53 per cent.)

(b) Foreign Countries	462·7	(47 per cent.)
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Total Imports from the World	<u>985·0</u>
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Source of Information.

'Statistical Abstract for the British Overseas Dominions and Protectorates (Cmd. 3198), 1928.'

REPORTS ON THE STATE OF SCIENCE, ETC.

Seismological Investigations.—*Thirty-fourth Report of Committee* (Professor H. H. TURNER, *Chairman*; Mr. J. J. SHAW, *Secretary*; Mr. C. VERNON BOYS, Dr. J. E. CROMBIE, Dr. C. DAVISON, Sir F. W. DYSON, Sir R. T. GLAZEBROOK, Dr. HAROLD JEFFREYS, Professor H. LAMB, Sir J. LARMOR, Professor A. E. H. LOVE, Professor H. M. MACDONALD, Dr. A. CRICHTON MITCHELL, Mr. R. D. OLDHAM, Professor H. C. PLUMMER, Rev. J. P. ROWLAND, S.J., Professor R. A. SAMPSON, Sir A. SCHUSTER, Sir NAPIER SHAW, Sir G. T. WALKER, and Dr. F. J. W. WHIPPLE). [*Drawn up by the Chairman except where otherwise mentioned.*]

General.

[Kindly note that this is the 34th report, and that those for 1927 and 1928 should have been numbered 32 and 33 instead of 31 and 32. It is drawn up earlier than usual (June 21) in view of the South African visit.]

We regret to record the death of Father Pigot of the Riverview Observatory, whose observations have often been of the greatest value in determining epicentres near Australia, especially in the days when the other Australian observatories had only seismographs of the Milne type, which gave readings of inferior accuracy. Also the death of Prof. G. Grablovitz on September 19, 1928, the doyen of seismology. He was for forty-three years director of the R. Osserv. Geodinamico di Casamicciola, founded as a consequence of the severe shocks of 1881 and 1883.

The new buildings at the University Observatory, Oxford, include two rooms in which the seismological computations can now be made in comparative comfort, and in one of which (the upper) 'The Milne Library' has been placed. Below them is the basement for seismographs presented to the University by Dr. J. E. Crombie, and named 'the Crombie Basement.' It contains a massive pier (8 ft. \times 4 ft. surface) for the two seismographs, which were mounted upon it in October 1928. One of them, indeed, was mounted in July, but it was found that the pier had not dried or otherwise settled down; and even in October it was found desirable to allow it further time at one end, the E.W. component being meanwhile transferred to a temporary pier on the basement floor. The two piers previously used in the Clarendon Basement had been erected forty years ago for Prof. C. V. Boys's 'Cavendish Experiment,' and had been kindly put at disposal during the years 1918-1928 by Prof. Lindemann. On the occasion of their return to the regular use of the laboratory in October 1928 a small brass plate was mounted on the wall of the basement recording their uses for the seismographs, and for the Cavendish Experiment, the history of which was recounted by Mr. C. V. Boys on November 23 to an appreciative audience. In the course of his lecture he recalled that his observations had on one occasion been interrupted by the occurrence of an earthquake, viz., that in Roumania on 1893 September 10d. 3h. 45m.

An earthquake with date 1928 April 22d. 20h. 13m. 50s., which partly destroyed the city of Corinth, was mentioned in the last report. The position of Corinth is $37^{\circ}9' \text{ N.}$, $22^{\circ}9' \text{ E.}$; that of the epicentre (according to readings received from Helwan, San Fernando, Toledo, Tortosa, Paris and Vienna) is not far from $40^{\circ}0' \text{ N.}$, $23^{\circ}0' \text{ E.}$ By the kindness of the hydrographer an interesting note has been received of a disturbance of the magnetic compass on H.M.S. *Argus* in $33^{\circ}38' \text{ N.}$, $24^{\circ}4' \text{ E.}$, sailing on an easterly course (286° true or $\text{N}71^{\circ} \text{ W.}$ standard).

Great care was clearly taken to relate the observed disturbance of 5° to the magnetic compasses rather than to the gyrocompasses, but one point is still in doubt, viz., whether the disturbance occurred at the time of the earthquake or (perhaps by some confusion with local time) two hours previously. Even in the latter case it may have been related to the earthquake. Prof. S. Chapman is investigating the matter from a magnetic point of view. Whatever may be the final outcome of this particular incident, it calls attention to the fact that, in the existence side by side

of magnetic and gyrocompasses, we have the means of observing temporary disturbances of the former which might previously have passed unnoticed.

In reporting the incident Commander Faulkner of H.M.S. *Argus* writes :—

As both magnetic compasses were deflected similarly, it is doubtful whether a vessel not fitted with gyrocompasses would have been aware of the disturbance. Unfortunately no azimuths could be taken during the phenomenon.

It is interesting to remark that the gyrocompasses are now good enough to be trusted against the magnetic. In this connection the duration of the perturbation is noteworthy. At '18-20 G.M.T.' the difference was 5° ; 'after 10 minutes the difference . . . began to decrease until at 19-10 G.M.T. the standard compass course became normal again—to be followed shortly after by the steering compass.'

[The times as noted are of course earlier than the earthquake shock : what makes the doubt is that they are noted as 'practically coincident with the earthquake which destroyed the town of Corinth.']

Instrumental.

The stations organised by Milne were equipped with his own simple undamped seismograph, which was suitable for pioneer work. As time went on he realised the need for damping, and asked Mr. J. J. Shaw to modify the instrument accordingly, but he did not live to see the successful result. The 'Milne-Shaw' seismograph is the direct successor of the pioneer 'Milne,' and is thus in a special way connected with the work of this committee. Mr. Shaw has supplied (at the cost of construction merely) many of these instruments for use in stations scattered over the world, some of them in direct touch with this committee, others quite independent of it. The work of construction has been carried out at his house (Sunnyside, Birmingham Road, West Bromwich) either by himself or directly under his supervision. The regrettable serious illness of Mr. Shaw interrupted this devoted work ; and though he is now happily restored to health, the arrangements for resuming the work have not yet been fully recovered. Nevertheless he is able to report as having been recently installed : Melbourne, one component ; Harvard University, two components ; Nizamiah Observatory, Hyderabad, the second component. Other machines have been ordered, and the committee is able to hope that Mr. Shaw will find it now possible to continue his important work of construction.

International.

The *Comptes Rendus* of the third meeting of the Seismological Section (at Prague, 1927, September 3–10) have been printed in a volume of 104+126 pages, the second part containing accounts, reports presented to the Section, bibliography, &c. The next meeting of the G. & G. Union has been fixed for 1930, August 18–25, at Stockholm.

The work of this committee of the British Association was at first not international in character, though world-wide. Milne's organisation of stations scattered over the world, and armed with his simple pioneer seismograph, was in the first instance confined to British stations, which reported to him at Shide. Their observations were printed in the Committee's circulars, under the heading of each observatory, and the collation of different observations for determining the epicentre and time of occurrence was not printed in detail : the results simply were printed (and these for considerable earthquakes only) for each year up to 1911. After Milne's death a commencement was made of giving details for the 'large earthquakes' from 1913 onwards ; smaller ones being gradually added until for the year 1917 the survey began to approach completeness. By request of the Seismological Section at its meeting in Rome in May 1922 the publication was made international, and the results for 1918 and following years have appeared as the *International Seismological Summary*. Only a small portion of the whole cost, however, has been provided from international funds. The cost of *preparation* has been borne partly by the B.A. subsidy of £100 a year from the Caird Fund, partly by the generosity of Dr. Crombie, partly by the Department of Scientific and Industrial Research, partly by the Royal Society, and partly by the University of Oxford. The cost of *printing* (which might have been provided from the international funds if the franc had maintained the value it had in 1922) has been in itself larger than the international grant ; but the Royal Society

has stepped in to meet the deficiency. The printing account to February 1928 is given as 'Annexe II bis' in the *Comptes Rendus* of the Prague meeting above-mentioned, and may be brought up to date as below :—

Provision.				Cost of Printing the Summary.					
			£						£
By Section of Seism. as				1918	...	...	...	...	241
noted in Annexe	...	1,064		1919	...	...	...	...	163
Received May 1928	...	81		1920	...	...	...	...	193
„ „ 1929	...	161		1921	...	...	...	...	146
		—	1,306	1922	...	...	...	...	200
To 1927, October 28, from				1923	...	...	...	...	267
Royal Society (noted)...	...	225		1924	...	...	...	...	238
From Royal Society 1928,				1925	...	...	...	...	280
July 20 ...	...	150							
		—	375						
			1,681						
Balance due	...	...	47						
			£1,728	Total	...	...	...	...	£1,728

Summary for three months ending	Sent to Press on	Interval in Months.	No. of Pages of Summary.	Rate in Pages per Year.
1918 Mar. 31	1923 Feb. 27	59-0	40	
June 30	June 11	59-3	48	
Sept. 30	Aug. 8	58-2	66	
Dec. 31	Oct. 23	57-8	64	242
1919 Mar. 31	Dec. 21	56-7	36	274
June 30	1924 Feb. 1	55-0	48	333
Sept. 30	Apr. 7	54-2	56	304
Dec. 31	May 29	52-9	32	288
1920 Mar. 31	July 16	51-5	50	324
June 30	Aug. 26	49-8	50	328
Sept. 30	Nov. 20	49-7	52	294
Dec. 31	1925 Jan. 24	48-8	48	305
1921 Mar. 31	Mar. 25	47-8	48	308
June 30	June 10	47-2	44	247
Sept. 30	July 31	46-0	40	260
Dec. 31	Oct. 1	45-0	44	258
1922 Mar. 31	Nov. 23	43-8	48	264
June 30	1926 Jan. 26	42-8	56	294
Sept. 30	Mar. 24	41-8	56	314
Dec. 31	May 12	40-4	64	360
1923 Mar. 31	Aug. 8	40-3	68	342
June 30	Oct. 17	39-6	64	342
Sept. 30	Dec. 19	38-6	110	415
Dec. 31	1927 Feb. 28	38-0	74	396
1924 Mar. 31	June 21	38-7	64	360
June 30	Aug. 20	37-7	68	376
Sept. 30	Nov. 15	37-5	86	322
Dec. 31	1928 Feb. 15	37-5	66	296
1925 Mar. 31	June 1	38-0	80	319
June 30	Aug. 27	37-9	100	326
Sept. 30	Nov. 28	38-0	72	305
Dec. 31	1929 Feb. 14	37-5	72	324
1926 Mar. 31	1929 Apr. 9	36-3	86	384

The increase in the work may also be indicated by the number of epicentres dealt with. Monthly counts of these were given in the last report, but the totals for the year were omitted by oversight. For the seven years 1918-1924 they are 372, 323, 324, 258, 310, 542, 473. [The total 542 for 1923 is unduly exaggerated by the number of aftershocks following the great Japanese earthquakes of 1923, September 1-2.] The total for 1925 is 481. The monthly totals are:—

J	F	M	A	M	J	J	A	S	O	N	D
37	47	37	36	55	55	50	40	32	29	26	37

The seven years 1918-24 showed a decided and rather sudden maximum in September, even when the exceptional year 1923 was excluded. There is no trace of this maximum in 1925.

Deep Focus.

It was mentioned in the last report that a paper showing the cases (a dozen or more) in which indications of deep focus had been reached independently at Oxford, and by Mr. Wadati in Japan, had been sent to him for publication in the *Tokio Geophysical Magazine*, in which his own paper (showing an independent method of detecting deep foci) appeared. Nothing, however, has been received or heard in reply up to the present, and inquiry is being made as to the fate of the paper.

The cases of abnormal focal depth determined at Oxford are of course not confined to the neighbourhood of Japan like those of Mr. Wadati. They have been given in detail in the *Summary*, and are indicated briefly in the *Catalogue of Earthquakes*

1918-1924, which the British Association kindly printed in connection with the last report.

The following cases of abnormal focal depth recently added to those may be noted

Date.			Epicentre.		Depth below normal.
	d.	h.	°	°	
1925	Jan. 28	18	52.8 N.	174.0 E.	+·010
	Jan. 30	17	52.8 N.	174.0 E.	+·010
	Mar. 1	2	48.2 N.	70.8 W.	+·010
	Mar. 8	11	35.0 N.	69.0 E.	+·030
	Mar. 15	13	10.8 S.	119.5 E.	+·015
	Mar. 15	15	10.8 S.	119.5 E.	+·015
	Mar. 26	10	5.4 N.	125.2 E.	+·040
	Mar. 29	21	7.5 N.	79.0 W.	+·010
	Apr. 19	15	33.0 N.	137.5 E.	+·045
	Apr. 26	8	55.0 S.	145.0 E.	-·030
	May 14	7	36.5 N.	70.5 E.	+·020
	May 15	18	30.5 N.	138.5 E.	+·050
	May 27	2	36.5 N.	133.0 E.	+·050
	June 7	23	3.0 N.	80.5 W.	+·045
	June 20	13	37.0 N.	72.0 E.	+·040
	June 23	16	0.0	75.0 W.	+·025
	Sept. 23	20	36.5 N.	70.5 E.	+·020
	Sept. 29	17	18.0 N.	64.0 W.	+·005
	Oct. 5	4	12.3 N.	85.8 W.	+·020
	Oct. 13	17	10.2 N.	42.8 W.	+·005
	Oct. 20	9	27.3 N.	138.5 E.	+·050
	Dec. 18	18	36.8 N.	69.5 E.	+·030
1926	Jan. 15	14	45.0 N.	143.0 E.	+·060
	Feb. 1	1	10.6 N.	65.6 W.	+·025
	Feb. 7	2	3.0 S.	151.5 E.	+·040
	Feb. 9	0	27.0 S.	59.5 W.	+·090
	Feb. 15	2	11.7 N.	89.6 W.	+·015
	Mar. 16	17	16.0 S.	171.0 W.	+·020
	Mar. 25	19	11.0 S.	134.0 E.	+·020

The cases of abnormally deep focus noticed in the years 1918.0-1926.25 are distributed as follows. The unit of depth is 0.010 radius of 40 miles. Occasionally the depth is estimated to .005; these cases have been assigned half to each of the neighbouring groups:—

Distribution of focal depths. (D)
(Unit of D is 0.010 radius.)

D =	1	2	3	4	5	6	7	8	9
O =	24	20	23	16	15	13	5	2	1
C ₁ =	98	58	34	20	12	7	4.1	2.4	1.4
C ₂ =	38	34	28	20	14	9	5.3	2.8	1.4
C ₃ =	26	25	23	19	14.5	9.6	5.3	2.5	0.9

At one time it seemed possible that there were certain critical depths near which the foci were likely to occur; but with the accumulation of more cases this hypothesis is not supported. The figures O (which are the observations) suggest rather a regular falling-off according to some exponential of the focal depth. The three lines below it are calculated from the formulæ

$$\begin{aligned}\log C_1 &= 2.22 - 0.23D. \\ \log C_2 &= 1.60 - 0.018 D^2. \\ \log C_3 &= 1.41 - 0.0020 D^3.\end{aligned}$$

C_3 fits the observations O best, especially for $D=1$ and $D=2$. But it is a question whether the fit ought to be good at these depths, for there may be many cases of small focal depth which have escaped detection owing to insufficiency of observations; and when $D=0$ the number of cases is certainly very large, though it is not easy to give a precise value to it.

The single case $D=9$ occurs on 1926, February 9d. 0h. with epicentre $27^{\circ}0$ S. $59^{\circ}5$ W. It is the deepest focus yet determined; but the evidence for this exceptional depth seems good. The epicentre is practically fixed by observations at La Plata, Sucre and La Paz, all within 15° of it; but nine observatories in Europe (azimuth 43°) then require a correction to Δ of more than 10° ; and two others in N. America (azimuth 346°) a correction of 10° . Four Asian stations at distances from 130° to 170° receive $[P]$ about 80 sec. early, and fourteen European stations with Δ from 94° to 117° receive $[S]$ about 2 min. too early. All the evidence hangs together. Moreover, though this is actually the greatest depth hitherto required, there are two cases requiring 0.080, not much less, on 1921 Dec. 18d. 15h. 29m. 24s. at $2^{\circ}5$ S. $71^{\circ}0$ W., and on 1922 Sept. 4d. 17h. 4m. 8s. at $9^{\circ}0$ S. $66^{\circ}0$ W. It will be seen that all three extreme cases occur in S. America. The six cases of 0.070 are as follows:—

		d.	h.	m.	s.	Lat.	Long.
1918	Apr.	10	2	3	44	$44^{\circ}0$ N.	$131^{\circ}0$ E.
1918	Dec.	25	10	21	10	$7^{\circ}0$ S.	$153^{\circ}0$ E.
1920	May	6	9	40	30	$44^{\circ}0$ N.	$131^{\circ}0$ E.
1920	July	2	18	41	5	$7^{\circ}0$ S.	$153^{\circ}0$ E.
1922	Jan.	17	3	50	24	$2^{\circ}0$ S.	$72^{\circ}0$ W.
1924	May	25	13	46	40	$19^{\circ}0$ S.	$179^{\circ}0$ E.

Of these six only one is in S. America, so that the other three cases seem to have a quite exceptional character.

Periodicities.

Attention has been chiefly directed to the period of approximately 21 minutes. Two papers have been published in the *Geophysical Supplement* to the R.A.S. Monthly Notices; one (April 1928) presenting the discussion of eleven separate series of repetitions from the same epicentre, apparently shows that the precise value of the period varies with the latitude, being about 21.2 min. near latitude 45° and less than 21.0 min. in seven other cases; the second paper (October 1928) deals with the earthquakes recorded in the Philippines in the nine years 1918–1926, which consistently show a periodicity near 20.993342 min. (given in the paper by an unfortunate oversight as 20.993342 min.). The character of the variation is a sharp rise in frequency (possibly *per saltum*) with a subsequent steady fall.

The total counts for twelve equal subdivisions of the period adopted are as follows, starting with the maximum:—

$O = 150 \quad 128 \quad 141 \quad 123 \quad 130 \quad 127 \quad 132 \quad 114 \quad 116 \quad 106 \quad 112 \quad 104$

Assuming a uniform slope of 3.4 per term we get

$C_1 = 142 \quad 138 \quad 135 \quad 132 \quad 128 \quad 125 \quad 122 \quad 119 \quad 115 \quad 112 \quad 109 \quad 105$
 $O - C_1 = +8 \quad -10 \quad +6 \quad -9 \quad +2 \quad +2 \quad +10 \quad -5 \quad +1 \quad -6 \quad +3 \quad -1$
 $O - C_3 = +3 \quad -5 \quad +1 \quad -4 \quad -3 \quad +7 \quad +3 \quad +2 \quad -4 \quad -1 \quad -2 \quad +4$

There is a curious feature in the residuals $O - C_1$, viz., the alternation of + and - signs, which makes the mean odd residual +5 and the mean even residual -5. If this difference is allowed for as in the line $O - C_2$, the sum of the squares of the residuals is reduced from 461 to 159. But the main feature of the O totals is clearly the drop of 3.4 per term. These are totals for nine years, so that for a single year the drop or slope would be $3.4/9 = .38$. In the paper these slopes are calculated for the separate years 1918–1926 and found to be

+21, +20, +60, +44, +44, +30, +21, +42, +55,

showing a mean value +37 with a mean departure of ± 13 . The evidence of the nine years is thus satisfactorily consistent.

But this valuable series of Philippine records does not begin with 1918 ; it extends back at least to 1890, and it was clearly desirable to examine the earlier years to see how far they support the evidence of 1918-26. This examination has been made, and the results are nearly ready for presentation, though owing to various circumstances the amount of work has been considerable.

Briefly, the earlier years show the periodicity indicated by 1918-26, with a slight change of period which is only reasonable ; but it has been necessary to examine another sensibly different periodicity. Further, the years 1890-1903, though not so valuable as those which follow, still contribute to the testimony, but require special treatment.

The Interchange of Seismological Information.

At the beginning of 1929 as the result of negotiations opened by the Director of the Meteorological Office, there was an important extension of the system of exchange of seismological information by wireless telegraphy. When large earthquakes occur, data collected by the Coast and Geodetic Survey of the United States are now added to the meteorological messages broadcast from Arlington. These messages are re-broadcast from the Eiffel Tower. To begin with, the broadcast data referred only to the seismograms at two selected stations. Since May the positions of the epicentres as determined by the Coast and Geodetic Survey have been given as well.

During the half year, January to June 1929, there were seventeen occasions on which details of earthquakes were broadcast from Arlington and picked up at the Air Ministry, London.

Particulars of the code used for the seismological reports can be obtained from the Superintendent of Kew Observatory, Richmond, Surrey.

Calculation of Mathematical Tables.—*Report of Committee* (Prof. J. W. NICHOLSON, *Chairman*; Dr. J. R. AIREY, *Secretary*; Drs. L. J. COMRIE and A. T. DOODSON; Prof. L. N. G. FILON, Drs. R. A. FISHER and J. HENDERSON; Prof. E. W. HOBSON; Mr. J. O. IRWIN, Profs. A. LODGE, A. E. H. LOVE and H. M. MACDONALD; Drs. A. J. THOMPSON and J. F. TOCHER; Mr. T. WHITWELL and Dr. J. WISHART).

(*Note.*—The Committee of Section A reports that owing to the special circumstances of the South African Meeting the full report of the Committee on the Calculation of Mathematical Tables could not be received. The following consists of such portions of the report as are at present available for publication.)

NEW TABLES IN COURSE OF CONSTRUCTION.

The present Report contains Prof. A. Lodge's tables of Harmonic Series, $\varphi(x)$, which extend over the range x from 0.0 to 60.3 by 0.1 intervals to sixteen places and x from 50.00 to 51.00 by 0.01 intervals to ten places with first and second differences. This function is equivalent to $\gamma + \frac{d}{dx} \log_e \Gamma(1+x)$, where

γ is Euler's constant, the value of which is given below to twenty decimal places.

Some other tables have been completed and others are nearing completion, which will, in due course, be submitted to the Committee for consideration. These include Zonal Harmonics with first derivative, $P_n(\cos \theta)$ and $\frac{d}{d\theta} P_n(\cos \theta)$, n from 1 to 20, θ from 0° to 90° by 5° intervals, to twelve places.

Gaussian functions $G_n^m(\mu)$, n and m from 11 to 20, μ from 0.00 to 1.00 by 0.05 intervals, eight or nine places.

Besselfunction product, $I_0^1 G_0^1$, argument $x \sqrt{-1}$, real part $V_r(x)$, imaginary part $V_u(x)$, x from 0.00 to 10.00 by 0.02 intervals and higher values of x , with the first ten zeros of these functions, six places.

Bessel functions and first and second derivatives, $J_\nu(x)$, $\frac{\delta}{\delta \nu} J_\nu(x)$, $\frac{\delta^2}{\delta \nu^2} J_\nu(x)$,

x from 1 to 20, and ν from $x-1$ to $x+1$ by 0.1 intervals, six, five and four places.

Bessel functions of imaginary order, $J_{ai}(x)$.

THE TABULATION OF THE SUMMATION FUNCTION FOR HARMONIC SERIES.

BY PROF. ALFRED LODGE.

$$\varphi(x) \equiv \left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \left(\frac{1}{3} - \frac{1}{x+3}\right) + \dots \text{ad inf.}$$

$$\text{in which } \varphi(x+1) = \frac{1}{x+1} + \varphi(x) \dots \dots \dots (1)$$

$$\text{When } x \text{ is an integer, } \varphi(x) = 1 + \frac{1}{2} + \frac{1}{3} + \dots + \frac{1}{x}.$$

$$\text{Also } \varphi\left(\frac{1}{2}\right) = \left(1 - \frac{2}{3}\right) + \left(\frac{1}{2} - \frac{2}{5}\right) + \left(\frac{1}{3} - \frac{2}{7}\right) + \dots$$

$$= 2\left(\frac{1}{2} - \frac{1}{3} + \frac{1}{4} - \frac{1}{5} + \dots\right)$$

$$= 2(1 - \log_e 2) \dots \dots \dots (2)$$

For small values of x the following formula is available:

$$\varphi(x) = \frac{x}{x+1} + A_2 x - A_3 x^2 + A_4 x^3 \dots - (-x)^{n-1} \left\{ A_n + \frac{x}{2^n(2+x)} + \frac{x}{3^n(3+x)} + \dots \right\}. \quad (3)$$

where $A_r \equiv \frac{1}{2^r} + \frac{1}{3^r} + \frac{1}{4^r} + \dots$ *ad inf.*,

but for general purposes the best formula seems to be

$$\varphi(x) = \gamma + \frac{1}{2} \log_e (x^2 + x) + R \quad \dots \dots \dots (4)$$

where $\gamma = 0.57721 \ 56649 \ 01532 \ 86060 \dots$

$$\text{and } \frac{1}{R} = 6 \left\{ (x^2 + x) + \frac{1}{5} - \frac{19}{525} (x^2 + x)^{-1} + \frac{13}{375} (x^2 + x)^{-2} + \dots \right\},$$

the first two terms of which are sufficient for tabulation purposes to seven or more decimal places when x exceeds seven.

The expression for R may also be written in either of the following forms:

$$R = \frac{1}{6(x^2 + x)} - \frac{1}{30(x^2 + x)^2} + \frac{4}{315(x^2 + x)^3} - \frac{1}{105(x^2 + x)^4} + \frac{32}{2310(x^2 + x)^5} + \dots$$

$$\begin{aligned} \text{or } R &= \frac{1}{6(x^2 + x + \frac{1}{2})} + \frac{19}{3150(x^2 + x)^3} - \frac{43}{5250(x^2 + x)^4} + \dots \\ &= \frac{1}{6(x^2 + x + \frac{1}{2})} + \left(\frac{1}{175} + \frac{1}{3150} \right) (x^2 + x)^{-3} - \left(\frac{1}{125} + \frac{1}{5250} \right) (x^2 + x)^{-4} + \dots \end{aligned}$$

The method adopted for the tabulation was the direct calculation and addition of the reciprocals of the successive integers up to $x=61$, and the calculation by formulæ (2) and (1) for the half integers, and the use of (4) for $x=50.1$ to 50.9 to 16 decimals, from which by means of (1) all the other values of the function were tabulated. The last place of decimals is necessarily approximate, but I do not think it is anywhere more than a unit out.

The later part of the work was much facilitated by using a wonderful table of reciprocals published in 1823, and kindly presented to me by the Rev. J. J. Milne.

A further check was obtained by independent calculation by (4) of the part between $x=10.1$ and $x=10.9$. Also $\varphi(0.1)$ was calculated from (3) and found to agree well with the value already calculated.

The table could be extended beyond its present limits by means of (1), or it could be dispensed with by using the formula (4).

Interpolations in the present tables could be made by either of the formulæ given below, or by the 'difference' method, which would, however, be very cumbrous in some of the earlier portions.

With a view to filling in a more complete table I have tabulated the function between $x=50$ and 51 to 0.01 intervals to 10 decimals. This would be a foundation for more detailed tabulation in the other dekads.

In an Appendix I give the method of obtaining the important formula (4), and also allied formulæ from which the sums of reciprocals of other odd powers could be obtained.

INTERPOLATION FORMULÆ.

First Method ; $\varphi(\alpha + x) = (1 + \Delta)^x \varphi(\alpha)$ leads to the series

$$\varphi(\alpha + x) = \varphi(\alpha) + \frac{x}{\alpha + 1} + \frac{x(1-x)}{2(\alpha + 1)(\alpha + 2)} + \frac{x(1-x)(2-x)}{3(\alpha + 1)(\alpha + 2)(\alpha + 3)} + \dots$$

Second Method : $\varphi(\alpha) = \gamma + \frac{1}{2} \log \alpha(\alpha + 1) + R_0$

$$\varphi(\alpha + x) = \gamma + \frac{1}{2} \log (\alpha + x)(\alpha + 1 + x) + R_1$$

$$\therefore \varphi(\alpha + x) - \varphi(\alpha) = \frac{1}{2} \left\{ \log \frac{\alpha + x}{\alpha} + \log \frac{\alpha + 1 + x}{\alpha + 1} \right\} - (R_0 - R_1)$$

$$= x \left(\frac{1}{2\alpha + x} + \frac{1}{2\alpha + 2 + x} \right) + \frac{1}{3} x^3 \left\{ \frac{1}{(2\alpha + x)^3} + \frac{1}{(2\alpha + 2 + x)^3} \right\} + \dots - (R_0 - R_1),$$

which is practically equal to $\frac{x}{2\alpha + x} + \frac{x}{2\alpha + 2 + x} - (R_0 - R_1)$

when x is small compared with α .

VALUES OF $\left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \left(\frac{1}{3} - \frac{1}{x+3}\right) + \dots \text{ad inf.}$

x		x	
0.0	0.00	5.4	2.35335 90607 855336
0.1	0.15346 07244 904561	5.5	2.37012 69953 014658
0.2	0.28817 57683 093447	5.6	2.38661 90129 874262
0.3	0.40802 47760 347333	5.7	2.40284 40284 713512
0.4	0.51583 11203 164167	5.8	2.41881 05320 674308
0.5	0.61370 56388 801094	5.9	2.43452 66162 332198
0.6	0.70326 31176 750092	6.0	2.45
0.7	0.78576 35397 750269	6.1	2.46523 80515 595792
0.8	0.86220 70981 953944	6.2	2.48024 78091 717082
0.9	0.93339 98260 655927	6.3	2.49503 60005 395190
1.0	1.00	6.4	2.50960 90607 855336
1.1	1.06255 16335 813652	6.5	2.52397 31491 476196
1.2	1.12150 91016 426781	6.6	2.53813 41645 025778
1.3	1.17725 55452 655025	6.7	2.55209 77598 146348
1.4	1.23011 68346 021310	6.8	2.56586 93555 968426
1.5	1.28037 23055 467760	6.9	2.57945 41524 651039
1.6	1.32826 31176 750092	7.0	2.59285 71428 571429
1.7	1.37399 88338 926739	7.1	2.60608 31219 821144
1.8	1.41776 26537 509500	7.2	2.61913 66980 605971
1.9	1.45971 56155 392769	7.3	2.63202 23019 093821
2.0	1.50	7.4	2.64474 41959 206688
2.1	1.53874 21097 718414	7.5	2.65730 64824 809530
2.2	1.57605 45561 881326	7.6	2.66971 31118 709988
2.3	1.61203 81539 611547	7.7	2.68196 78896 847646
2.4	1.64678 35012 687977	7.8	2.69407 44838 019708
2.5	1.68037 23055 467760	7.9	2.70603 64309 461165
2.6	1.71287 85022 903938	8.0	2.71785 71428 571429
2.7	1.74436 92042 630443	8.1	2.72953 99121 055712
2.8	1.77490 55108 938071	8.2	2.74108 79175 727922
2.9	1.80454 32017 461735	8.3	2.75250 42296 202254
3.0	1.83333 33333 333333	8.4	2.76379 18149 682878
3.1	1.86132 27549 331317	8.5	2.77495 35413 044824
3.2	1.88855 45561 881326	8.6	2.78599 21816 384407
3.3	1.91506 84569 914577	8.7	2.79691 04184 203968
3.4	1.94090 11483 276212	8.8	2.80771 08474 383344
3.5	1.96608 65912 610618	8.9	2.81839 59815 079143
3.6	1.99065 62800 681716	9.0	2.82896 82539 682540
3.7	2.01463 94745 333146	9.1	2.83943 00219 956811
3.8	2.03806 34056 306492	9.2	2.84978 35697 467052
3.9	2.06095 34581 564299	9.3	2.86003 11113 406555
4.0	2.08333 33333 333333	9.4	2.87017 47936 916921
4.1	2.10522 51939 575220	9.5	2.88021 66991 992192
4.2	2.12664 97942 833707	9.6	2.89015 88483 051073
4.3	2.14762 65965 263414	9.7	2.90000 32019 255514
4.4	2.16817 38756 003485	9.8	2.90975 16637 648650
4.5	2.18830 88134 832840	9.9	2.91940 60825 180153
4.6	2.20804 75844 159977	10.0	2.92896 82539 682540
4.7	2.22740 54319 801231	10.1	2.93843 99229 857801
4.8	2.24639 67389 639825	10.2	2.94782 27854 329797
4.9	2.26503 50908 094910	10.3	2.95711 84899 814322
5.0	2.28333 33333 333333	10.4	2.96632 86398 455382
5.1	2.30130 36253 300709	10.5	2.97545 47944 373145
5.2	2.31895 74865 910630	10.6	2.98449 84709 466168
5.3	2.33630 58418 093603	10.7	2.99346 11458 507850

VALUES OF $\left(1 - \frac{1}{x+1}\right) + \left(1 - \frac{1}{x+2}\right) + \left(1 - \frac{1}{x+3}\right) + \dots$ *ad inf.*—contd.

x		x	
10.8	3.00234 42563 574576	16.2	3.39277 36925 482304
10.9	3.01114 92017 840704	16.3	3.39874 20884 414000
11.0	3.01987 73448 773449	16.4	3.40467 50841 887236
11.1	3.02853 00130 758702	16.5	3.41057 30971 302170
11.2	3.03710 84997 186940	16.6	3.41643 65372 710434
11.3	3.04561 40652 026712	16.7	3.42226 58074 523479
11.4	3.05404 79380 911523	16.8	3.42806 13035 171475
11.5	3.06241 13161 764449	16.9	3.43382 34144 714491
11.6	3.07070 53674 983409	17.0	3.43955 25226 407579
11.7	3.07893 12313 208706	17.1	3.44524 90038 221346
11.8	3.08709 00190 693220	17.2	3.45091 32274 319513
11.9	3.09518 28152 294485	17.3	3.45654 55566 494924
12.0	3.10321 06782 106782	17.4	3.46214 63485 565397
12.1	3.11117 46411 750438	17.5	3.46771 59542 730741
12.2	3.11907 57128 334481	17.6	3.47325 47190 892253
12.3	3.12691 48782 108013	17.7	3.47876 29825 935909
12.4	3.13469 30993 814749	17.8	3.48424 10787 980464
12.5	3.14241 13161 764449	17.9	3.48968 93362 591586
12.6	3.15007 04468 634203	18.0	3.49510 80781 963135
12.7	3.15767 13888 011855	18.1	3.50049 76226 066650
12.8	3.16521 50190 693220	18.2	3.50585 82823 770063
12.9	3.17270 21950 744098	18.3	3.51119 03653 926618
13.0	3.18013 37551 337551	18.4	3.51649 41746 434962
13.1	3.18751 05190 376392	18.5	3.52177 00083 271282
13.2	3.19483 32885 910239	18.6	3.52701 81599 494403
13.3	3.20210 28481 356133	18.7	3.53223 89184 224679
13.4	3.20931 99650 531166	18.8	3.53743 25681 597485
13.5	3.21648 53902 505190	18.9	3.54259 93891 692116
13.6	3.22359 98586 281262	19.0	3.54773 96571 436819
13.7	3.23066 40895 311125	19.1	3.55285 36435 490734
13.8	3.23767 87871 852641	19.2	3.55794 16157 103396
13.9	3.24464 46411 175752	19.3	3.56300 38368 952525
14.0	3.25156 23265 623266	19.4	3.56804 05663 960735
14.1	3.25843 25048 532420	19.5	3.57305 20596 091794
14.2	3.26525 58238 022915	19.6	3.57803 85681 127056
14.3	3.27203 29180 656832	19.7	3.58300 03397 422648
14.4	3.27876 44094 975611	19.8	3.58793 76186 647990
14.5	3.28545 09074 918983	19.9	3.59285 06454 506186
14.6	3.29209 30093 130577	20.0	3.59773 96571 436819
14.7	3.29869 13004 154663	20.1	3.60260 48873 301679
14.8	3.30524 63547 528316	20.2	3.60744 65662 053891
14.9	3.31175 87350 773068	20.3	3.61226 49206 390949
15.0	3.31822 89932 289932	20.4	3.61706 01742 392108
15.1	3.32465 76704 161559	20.5	3.62183 25474 140575
15.2	3.33104 52974 865020	20.6	3.62658 22574 330940
15.3	3.33739 23951 898662	20.7	3.63130 95184 862262
15.4	3.34369 94744 326260	20.8	3.63601 45417 417221
15.5	3.34996 70365 241564	20.9	3.64069 75354 027717
15.6	3.35619 55734 156218	21.0	3.64535 87047 627295
15.7	3.36238 55679 313898	21.1	3.64999 82522 590779
15.8	3.36853 74939 933380	21.2	3.65461 63775 261438
15.9	3.37465 18168 383131	21.3	3.65921 32774 466066
16.0	3.38072 89932 289932	21.4	3.66378 91462 018276
16.1	3.38676 94716 583919	21.5	3.66834 41753 210342

VALUES OF $\left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \left(\frac{1}{3} - \frac{1}{x+3}\right) + \dots$ *ad inf.*—contd.

x		x	
21.6	3.67287 85537 293903	27.0	3.89145 67532 520824
21.7	3.67739 24677 949819	27.1	3.89508 61229 601116
21.8	3.68188 61013 747496	27.2	3.89870 23693 928280
21.9	3.68635 96358 593927	27.3	3.90230 55871 019231
22.0	3.69081 32502 172750	27.4	3.90589 58696 210134
22.1	3.69524 71210 373584	27.5	3.90947 33094 802026
22.2	3.69966 14225 711889	27.6	3.91303 79982 203840
22.3	3.70405 63267 739609	27.7	3.91659 00264 072898
22.4	3.70843 20033 446847	27.8	3.92012 94836 452912
22.5	3.71278 86197 654787	27.9	3.92365 64585 909563
22.6	3.71712 63413 400097	28.0	3.92717 10389 663681
22.7	3.72144 53312 311053	28.1	3.93067 33115 722113
22.8	3.72574 57504 975566	28.2	3.93416 33623 006295
22.9	3.73002 77581 301351	28.3	3.93764 12761 478595
23.0	3.73429 15110 [*] 868402	28.4	3.94110 71372 266472
23.1	3.73853 71643 274017	28.5	3.94456 10287 784482
23.2	3.74276 48708 470509	28.6	3.94800 30331 854190
23.3	3.74697 47817 095832	28.7	3.95143 32319 822027
23.4	3.75116 70460 797275	28.8	3.95485 17058 675135
23.5	3.75534 18112 548404	28.9	3.95825 85347 155238
23.6	3.75949 92226 959419	29.0	3.96165 37975 870577
23.7	3.76363 94240 581095	29.1	3.96503 75727 405962
23.8	3.76776 25572 202457	29.2	3.96840 99376 430952
23.9	3.77186 87623 142355	29.3	3.97177 09689 806240
24.0	3.77595 81777 535069	29.4	3.97512 07426 688241
24.1	3.78003 09402 610117	29.5	3.97845 93338 631939
24.2	3.78408 71848 966377	29.6	3.98178 68169 692028
24.3	3.78812 70450 840688	29.7	3.98510 32656 522363
24.4	3.79215 06526 371045	29.8	3.98840 87528 473792
24.5	3.79615 81377 854526	29.9	3.99170 33507 690355
24.6	3.80014 96292 000070	30.0	3.99498 71309 203911
24.7	3.80412 52540 176237	30.1	3.99826 01641 027224
24.8	3.80808 51378 654070	30.2	4.00152 25204 245522
24.9	3.81202 94048 845166	30.3	4.00477 42693 106570
25.0	3.81595 81777 535069	30.4	4.00801 54795 109293
25.1	3.81987 15777 112109	30.5	4.01124 62191 090956
25.2	3.82376 97245 791774	30.6	4.01446 65555 312943
25.3	3.82765 27367 836735	30.7	4.01767 65555 545165
25.4	3.83152 07313 772620	30.8	4.02087 62853 149117
25.5	3.83537 38240 599624	30.9	4.02406 58103 159611
25.6	3.83921 21292 000070	31.0	4.02724 51954 365201
25.7	3.84303 57598 541995	31.1	4.03041 45049 387353
25.8	3.84684 48277 878876	31.2	4.03357 38024 758342
25.9	3.85063 94434 945552	31.3	4.03672 31510 997944
26.0	3.85441 97162 150453	31.4	4.03986 26132 688911
26.1	3.85818 57539 564216	31.5	4.04299 22508 551273
26.2	3.86193 76635 104751	31.6	4.04611 21251 515474
26.3	3.86567 55504 718865	31.7	4.04922 22968 794376
26.4	3.86939 95192 560499	31.8	4.05232 28261 954148
26.5	3.87310 96731 165662	31.9	4.05541 37726 984062
26.6	3.87680 61141 624130	32.0	4.05849 51954 365201
26.7	3.88048 89433 747988	32.1	4.06156 71529 138132
26.8	3.88415 82606 237085	32.2	4.06462 97030 969522
26.9	3.88781 41646 841463	32.3	4.06768 29034 217758

VALUES OF $\left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \left(\frac{1}{3} - \frac{1}{x+3}\right) + \dots$ *ad inf.*—contd.

x		x	
32.4	4.07072 68107 997553	37.8	4.22269 39624 662992
32.5	4.07376 14816 243581	37.9	4.22530 13781 596668
32.6	4.07678 69717 773143	38.0	4.22790 20132 953503
32.7	4.07980 33366 347893	38.1	4.23049 59030 454702
32.8	4.08281 06310 734636	38.2	4.23308 30823 092022
32.9	4.08580 89094 765217	38.3	4.23566 35857 155947
33.0	4.08879 82257 395504	38.4	4.23823 74476 263489
33.1	4.09177 86332 763509	38.5	4.24080 47021 385639
33.2	4.09475 01850 246631	38.6	4.24336 53830 874458
33.3	4.09771 29334 518058	38.7	4.24591 95240 489832
33.4	4.10066 69305 602344	38.8	4.24846 71583 425878
33.5	4.10361 22278 930148	38.9	4.25100 83190 337028
33.6	4.10654 88765 392191	39.0	4.25354 30389 363760
33.7	4.10947 69271 392403	39.1	4.25607 13506 158027
33.8	4.11239 64298 900317	39.2	4.25859 32863 908349
33.9	4.11530 74345 502680	39.3	4.26110 88783 364598
34.0	4.11820 99904 454328	39.4	4.26361 81582 862474
34.1	4.12110 41464 728319	39.5	4.26612 11578 347664
34.2	4.12398 99511 065344	39.6	4.26861 79083 399711
34.3	4.12686 74524 022431	39.7	4.27110 84409 255575
34.4	4.12973 66980 020948	39.8	4.27359 27864 832914
34.5	4.13259 77351 393916	39.9	4.27607 09756 753069
34.6	4.13545 06106 432653	40.0	4.27854 30389 363760
34.7	4.13829 53709 432749	40.1	4.28100 90064 761518
34.8	4.14113 20620 739397	40.2	4.28346 89082 813821
34.9	4.14396 07296 792079	40.3	4.28592 27741 180976
35.0	4.14678 14190 168613	40.4	4.28837 06335 337722
35.1	4.14959 41749 628603	40.5	4.29081 25158 594578
35.2	4.15239 90420 156253	40.6	4.29324 84502 118923
35.3	4.15519 60643 002601	40.7	4.29567 84654 955820
35.4	4.15798 52855 727163	40.8	4.29810 25904 048600
35.5	4.16076 67492 238987	40.9	4.30052 08534 259181
35.6	4.16354 04982 837147	41.0	4.30293 32828 388150
35.7	4.16630 65754 250676	41.1	4.30533 99067 194608
35.8	4.16906 50229 677945	41.2	4.30774 07529 415763
35.9	4.17181 58828 825505	41.3	4.31013 58491 786302
36.0	4.17455 91967 946391	41.4	4.31252 52229 057528
36.1	4.17729 50059 877911	41.5	4.31490 89014 016265
36.2	4.18002 33514 078905	41.6	4.31728 69117 503538
36.3	4.18274 42736 666513	41.7	4.31965 92808 433039
36.4	4.18545 78130 452438	41.8	4.32202 60353 809365
36.5	4.18816 40094 978713	41.9	4.32438 72018 746055
36.6	4.19086 29026 552994	42.0	4.32674 28066 483388
36.7	4.19355 45318 283374	42.1	4.32909 28758 406010
36.8	4.19623 89360 112727	42.2	4.33143 74354 060313
36.9	4.19891 61538 852605	42.3	4.33377 65111 171645
37.0	4.20158 62238 216661	42.4	4.33611 01285 661302
37.1	4.20424 91838 853652	42.5	4.33843 83131 663324
37.2	4.20690 50718 379980	42.6	4.34076 10901 541097
37.3	4.20955 39251 411822	42.7	4.34307 84845 903765
37.4	4.21219 57809 596823	42.8	4.34539 05213 622449
37.5	4.21483 06761 645379	42.9	4.34769 72251 846288
37.6	4.21745 86473 361505	43.0	4.34999 86206 018272
37.7	4.22007 97307 673294	43.1	4.35229 47319 890928

VALUES OF $\left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \left(\frac{1}{3} - \frac{1}{x+3}\right) + \dots$ *ad inf.*—contd.

x		x	
43.2	4.35458 55835 541794	48.6	4.47109 19817 121026
43.3	4.35687 11993 388735	48.7	4.47312 65002 342828
43.4	4.35915 16032 205081	48.8	4.47515 68880 356153
43.5	4.36142 68189 134588	48.9	4.47718 31618 549062
43.6	4.36369 68699 706234	49.0	4.47920 53383 294251
43.7	4.36596 17797 848845	49.1	4.48122 34339 957253
43.8	4.36822 15715 905554	49.2	4.48323 74652 904547
43.9	4.37047 62684 648110	49.3	4.48524 74485 511587
44.0	4.37272 58933 290999	49.4	4.48725 34000 170759
44.1	4.37497 04689 505441	49.5	4.48925 53358 299248
44.2	4.37721 00179 433197	49.6	4.49125 32720 346832
44.3	4.37944 45627 700248	49.7	4.49324 72245 803593
44.4	4.38167 41257 430306	49.8	4.49523 72093 207559
44.5	4.38389 87290 258183	49.9	4.49722 32420 152268
44.6	4.38611 83946 343006	50.0	4.49920 53383 294251
44.7	4.38833 31444 381283	50.1	4.50118 35138 360447
44.8	4.39054 30001 619840	50.2	4.50315 77840 155543
44.9	4.39274 79833 868600	50.3	4.50512 81642 569241
45.0	4.39494 81155 513221	50.4	4.50709 46698 583457
45.1	4.39714 34179 527614	50.5	4.50905 73160 279446
45.2	4.39933 39117 486294	50.6	4.51101 61178 844856
45.3	4.40151 96179 576627	50.7	4.51297 10904 580713
45.4	4.40370 05574 610923	50.8	4.51492 22486 908346
45.5	4.40587 67510 038403	50.9	4.51686 96074 376237
45.6	4.40804 82191 957041	51.0	4.51881 31814 666800
45.7	4.41021 49825 125266	51.1	4.52075 29854 603108
45.8	4.41237 70612 973552	51.2	4.52268 90340 155543
45.9	4.41453 44757 615877	51.3	4.52462 13416 448383
46.0	4.41668 72459 861048	51.4	4.52654 99227 766336
46.1	4.41883 53919 223926	51.5	4.52847 47917 561000
46.2	4.42097 89333 936511	51.6	4.53039 59628 457259
46.3	4.42311 78900 958917	51.7	4.53231 34502 259630
46.4	4.42525 22815 990233	51.8	4.53422 72679 958539
46.5	4.42738 21273 479263	51.9	4.53613 74301 736545
46.6	4.42950 74466 635152	52.0	4.53804 39506 974492
46.7	4.43162 82587 437900	52.1	4.53994 68434 257619
46.8	4.43374 45826 648766	52.2	4.54184 61221 381597
46.9	4.43585 64373 820568	52.3	4.54374 18005 358517
47.0	4.43796 38417 307856	52.4	4.54563 38922 422825
47.1	4.44006 68144 277005	52.5	4.54752 24108 037190
47.2	4.44216 53740 716172	52.6	4.54940 73696 898324
47.3	4.44425 95391 445175	52.7	4.55128 87822 942742
47.4	4.44634 93280 125254	52.8	4.55316 66619 352478
47.5	4.44843 47589 268737	52.9	4.55504 10218 560742
47.6	4.45051 58500 248598	53.0	4.55691 18752 257511
47.7	4.45259 26193 307920	53.1	4.55877 92351 395095
47.8	4.45466 50847 569268	53.2	4.56064 31146 193627
47.9	4.45673 32641 043950	53.3	4.56250 35266 146510
48.0	4.45879 71750 641189	53.4	4.56436 04840 025821
48.1	4.46085 68352 177213	53.5	4.56621 39995 887658
48.2	4.46291 22620 384222	53.6	4.56806 40861 077428
48.3	4.46496 34728 919295	53.7	4.56991 07562 235107
48.4	4.46701 04850 373188	53.8	4.57175 40225 300434
48.5	4.46905 33156 279046	53.9	4.57359 38975 518070

VALUES OF $\left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \left(\frac{1}{3} - \frac{1}{x+3}\right) + \dots$ *ad inf.*—contd.

x		x	
54.0	4.57543 03937 442696	57.2	4.63248 53529 387605
54.1	4.57726 35234 944079	57.3	4.63421 69118 399149
54.2	4.57909 32991 212077	57.4	4.63594 54777 013612
54.3	4.58091 97328 761611	57.5	4.63767 10608 520687
54.4	4.58274 28369 437586	57.6	4.63939 36715 676318
54.5	4.58456 26234 419768	57.7	4.64111 33200 706379
54.6	4.58637 91044 227611	57.8	4.64283 00165 310308
54.7	4.58819 22918 725052	57.9	4.64454 37710 664722
54.8	4.59000 21977 125251	58.0	4.64625 45937 426983
54.9	4.59180 88337 995302	58.1	4.64796 24945 738759
55.0	4.59361 22119 260878	58.2	4.64966 74835 229529
55.1	4.59541 23438 210866	58.3	4.65136 95705 020076
55.2	4.59720 92411 501932	58.4	4.65306 87653 725941
55.3	4.59900 29155 163058	58.5	4.65476 50779 460858
55.4	4.60079 33784 600041	58.6	4.65645 85179 840141
55.5	4.60258 06414 599948	58.7	4.65814 90951 984062
55.6	4.60436 47159 335525	58.8	4.65983 68192 521192
55.7	4.60614 56132 369576	58.9	4.66152 16997 591716
55.8	4.60792 33446 659302	59.0	4.66320 37462 850712
55.9	4.60969 79214 560597	59.1	4.66488 29683 471416
56.0	4.61146 93547 832306	59.2	4.66655 93754 148448
56.1	4.61323 76557 640457	59.3	4.66823 29769 101020
56.2	4.61500 28354 562430	59.4	4.66990 37822 076109
56.3	4.61676 49048 591122	59.5	4.67157 18006 351614
56.4	4.61852 38749 139048	59.6	4.67323 70414 739470
56.5	4.62027 97565 042426	59.7	4.67489 95139 588752
56.6	4.62203 25604 565207	59.8	4.67655 92272 788751
56.7	4.62378 22975 403086	59.9	4.67821 61905 772017
56.8	4.62552 89784 687471	60.0	4.67987 04129 517378
56.9	4.62727 26138 989419	60.1	4.68152 19034 552946
57.0	4.62901 32144 323534	60.2	4.68317 06710 959081
57.1	4.63075 07906 151840	60.3	4.68481 67248 371335

$$\varphi(x) = \sum_{r=1}^{r=\infty} \left(\frac{1}{r} - \frac{1}{x+r} \right)$$

Expanded portion of the Table.

x	$\varphi(x)$	Δ	$-\Delta^2$	x	$\varphi(x)$	Δ	$-\Delta^2$
50·00	4·4992053383	1979937	391	50·50	4·5090573160	1960529	384
50·01	4033320	9546	392	50·51	2533689	1960145	384
50·02	6012866	9154	392	50·52	4493834	1959761	384
50·03	7992020	8762	391	50·53	6453595	9377	383
50·04	9970782	8371	392	50·54	8412972	8994	385
50·05	4·5001949153	7979	391	50·55	4·5100371966	8609	383
50·06	3927132	7588	392	50·56	2330575	8226	384
50·07	5904720	7196	390	50·57	4288801	7842	382
50·08	7881916	6806	390	50·58	6246643	7460	384
50·09	9858722	6416	391	50·59	8204103	7076	383
50·10	4·5011835138	6025	390	50·60	4·5110161179	6693	383
50·11	3811163	5635	391	50·61	2117872	6310	382
50·12	5786798	5244	390	50·62	4074182	5928	382
50·13	7762042	4854	389	50·63	6030110	5546	383
50·14	9736896	4465	390	50·64	7985656	5163	382
50·15	4·5021711361	4075	390	50·65	9940819	4781	382
50·16	3685436	3685	390	50·66	4·5121895600	4399	382
50·17	5659121	3295	389	50·67	3849999	4017	382
50·18	7632416	2906	388	50·68	5804016	3635	381
50·19	9605322	2518	390	50·69	7757651	3254	382
50·20	4·5031577840	2128	388	50·70	9710905	2872	381
50·21	3549968	1740	389	50·71	4·5131663777	2491	382
50·22	5521708	1351	389	50·72	3616268	2109	380
50·23	7493059	0962	388	50·73	5568377	1729	381
50·24	9464021	0574	389	50·74	7520106	1348	381
50·25	4·5041434595	1970185	388	50·75	9471454	0967	380
50·26	3404780	1969797	387	50·76	4·5141422421	0587	380
50·27	5374577	9410	388	50·77	3373008	1950207	381
50·28	7343987	9022	388	50·78	5323215	1949826	380
50·29	9313009	8634	387	50·79	7273041	9446	380
50·30	4·5051281643	8247	388	50·80	9222487	9066	380
50·31	3249890	7859	387	50·81	4·5151171553	8686	379
50·32	5217749	7472	387	50·82	3120239	8307	380
50·33	7185221	7085	386	50·83	5068546	7927	379
50·34	9152306	6699	388	50·84	7016473	7548	380
50·35	4·5061119005	6311	386	50·85	8964021	7168	379
50·36	3085316	5925	386	50·86	4·5160911189	6789	378
50·37	5051241	5539	386	50·87	2857978	6411	379
50·38	7016780	5153	387	50·88	4804389	6032	379
50·39	8981933	4766	386	50·89	6750421	5653	379
50·40	4·5070946699	4380	386	50·90	8696074	5274	378
50·41	2911079	3994	385	50·91	4·5170641348	4896	377
50·42	4875073	3609	385	50·92	2586244	4519	379
50·43	6838682	3224	386	50·93	4530763	4140	377
50·44	8801906	2838	386	50·94	6474903	3763	378
50·45	4·5080764744	2452	384	50·95	8418666	3385	378
50·46	2727196	2068	385	50·96	4·5180362051	3007	378
50·47	4689264	1683	384	50·97	2305058	2629	377
50·48	6650947	1299	385	50·98	4247687	2252	376
50·49	4·5088612246	1960914	385	50·99	6189939	1941876	
				51·00	4·5188131815		

APPENDIX.

On the connection of the inverse powers of $x(x-1)$ and $x(x+1)$, with the sums of the inverse odd powers of the successive numbers $x, x+1, x+2$, etc.

$$\frac{1}{x(x-1)} = \frac{1}{x^2} \left(1 + \frac{1}{x} + \frac{1}{x^2} + \frac{1}{x^3} + \dots \right)$$

Changing x into $x+1$, which is the same thing as changing the sign of x ,

$$\frac{1}{x(x+1)} = \frac{1}{x^2} \left(1 - \frac{1}{x} + \frac{1}{x^2} - \frac{1}{x^3} + \dots \right)$$

$$\therefore \frac{1}{x(x-1)} - \frac{1}{x(x+1)} = 2 \left(\frac{1}{x^3} + \frac{1}{x^5} + \dots \right)$$

Hence, writing a series of lines in which each is obtained from the preceding by changing x into $x+1$, and adding, we get finally

$$\begin{aligned} \frac{1}{2x(x-1)} &= \frac{1}{x^3} + \frac{1}{(x+1)^3} + \dots \text{ ad inf.} \\ &+ \frac{1}{x^5} + \frac{1}{(x+1)^5} + \dots \\ &+ \dots \\ &+ \dots \text{ ad inf.} \end{aligned}$$

which may be written $\sum \frac{1}{x^3} + \sum \frac{1}{x^5} + \sum \frac{1}{x^7} + \dots$

$$\text{Also} \quad \frac{1}{x^2(x-1)^2} = \frac{1}{x^4} \left(1 + \frac{2}{x} + \frac{3}{x^2} + \dots \right)$$

and therefore, by a similar process,

$$\frac{1}{2x^2(x-1)^2} = 2 \sum \frac{1}{x^5} + 4 \sum \frac{1}{x^7} + 6 \sum \frac{1}{x^9} + \dots$$

and, in general, r being a positive integer,

$$\frac{1}{2x^r(x-1)^r} = r \sum \frac{1}{x^{2r+1}} + \frac{r(r+1)(r+2)}{1 \cdot 2 \cdot 3} \sum \frac{1}{x^{2r+3}} + \dots$$

Hence, by choosing suitable coefficients, the quantities $\sum \frac{1}{x^3}, \sum \frac{1}{x^5}, \dots$ or

any given combination of these, can be expressed as functions of $\frac{1}{x(x-1)}$, i.e. in a series of its powers.

All this holds whether x is an integer or a fraction, so long as it is positive and greater than 1.

To obtain the series of the first inverse powers of successive numbers as a function of $x(x-1)$ it is necessary to have recourse to logarithms.

$$\text{Now } \frac{1}{2} \log \frac{x+1}{x-1} = \frac{1}{x} + \frac{1}{3x^3} + \frac{1}{5x^5} + \dots$$

$$\frac{1}{2} \log \frac{x+2}{x} = \frac{1}{x+1} + \frac{1}{3(x+1)^3} + \dots$$

$$\frac{1}{2} \log \frac{x+3}{x+1} = \frac{1}{x+2} + \frac{1}{3(x+2)^3} + \dots$$

$$\dots \dots \dots$$

$$\frac{1}{2} \log \frac{x+r+1}{x+r-1} = \frac{1}{x+r} + \frac{1}{3(x+r)^3} + \dots$$

$$\text{and the sum} = \frac{1}{2} \log \frac{(x+r)(x+r+1)}{x(x-1)} = \frac{1}{2} \log (x+r)(x+r+1) - \frac{1}{2} \log x(x-1).$$

$$\text{Now the limiting value of } 1 + \frac{1}{2} + \dots + \frac{1}{r} = \log r + \gamma$$

$$\text{where } \gamma = .57721 \ 56649 \ 01532 \ 86060 \dots$$

$$\begin{aligned} \therefore \left(1 - \frac{1}{x}\right) + \left(\frac{1}{2} - \frac{1}{x+1}\right) + \dots + \left(\frac{1}{r} - \frac{1}{x+r}\right) + \frac{1}{2} \log (x+r)(x+r+1) - \log r \\ = \frac{1}{2} \log x(x-1) + \gamma + \frac{1}{3x^3} + \text{etc. as above,} \end{aligned}$$

where γ^1 becomes γ in the limit when $r \rightarrow \infty$.

Now the limit of $\frac{1}{2} \log (x+r)(x+r+1) - \log r$ is $\log 1$, i.e. zero, when $r \rightarrow \infty$.

$$\begin{aligned} \therefore \left(1 - \frac{1}{x}\right) + \left(\frac{1}{2} - \frac{1}{x+1}\right) + \dots \text{ ad inf.} \\ = \frac{1}{2} \log x(x-1) + \gamma + \frac{1}{3} \sum \frac{1}{x^3} + \frac{1}{5} \sum \frac{1}{x^5} + \dots \end{aligned}$$

and, changing x into $x+1$,

$$\left(1 - \frac{1}{x+1}\right) + \left(\frac{1}{2} - \frac{1}{x+2}\right) + \dots = \gamma + \frac{1}{2} \log x(x+1) + \frac{1}{3} \sum \frac{1}{(x+1)^3} + \dots$$

If x is an integer, the left-hand side becomes $1 + \frac{1}{2} + \dots + \frac{1}{x}$.

We have therefore established this as a function of $x(x+1)$,

$$\text{and } 1 + \frac{1}{2} + \dots + \frac{1}{x-1} \text{ is the same function of } x(x-1).$$

This completes the theorem regarding the series of all the odd powers.

To find the coefficients of the powers of $[x(x-1)]^{-1}$ requisite to represent any function $A_1 \sum \frac{1}{x^3} + A_2 \sum \frac{1}{x^5} + \dots + A_r \sum \frac{1}{x^{2r+1}} + \dots$

Let a_r denote the coefficient of $[x(x-1)]^{-r}$.

Then the following table will furnish the linear equations giving the values A_1 , etc., in terms of a_1, \dots ; and their solutions will determine a_1, \dots in terms of A_1, \dots .

	A_1	A_2	A_3	A_4	A_5	A_6
a_1	2	2	2	2	2	2
a_2	...	4	8	12	16	20
a_3	6	20	42	72
a_4	8	40	112
a_5	10	70
a_6	12

The table is to be read vertically. Thus

$$2a_1 = A_1$$

$$2a_1 + 4a_2 = A_2$$

$$2a_1 + 8a_2 + 6a_3 = A_3$$

etc.

whence

$$2a_1 = A_1$$

$$4a_2 = A_2 - A_1, \text{ or, symbolically, } \Delta A_1$$

$$6a_3 = A_3 - 2A_2 + A_1 = \Delta^2 A_1,$$

after which the results are not quite so simple. Thus

$$2a_3 + 8a_4 = A_4 - 3A_3 + 3A_2 - A_1 = \Delta^3 A_1,$$

$$16a_4 + 10a_5 = A_5 - 3A_4 + 3A_3 - A_2 = \Delta^3 A_2$$

$$30a_5 + 12a_6 = A_6 - 4A_5 + 6A_4 - 4A_3 + A_2 = \Delta^4 A_2$$

and beyond this:

$$32a_5 + 64a_6 + 14a_7 = \Delta^4 A_3$$

$$64a_6 + 98a_7 + 16a_8 = \Delta^5 A_3$$

$$126a_7 + 144a_8 + 18a_9 = \Delta^6 A_3.$$

But only the earlier coefficients are as a rule needed.

The coefficients required for $\sum \frac{1}{x^3}$ are $a_1 = \frac{1}{2}$; $a_2 = -\frac{1}{4}$; $a_3 = \frac{1}{6}$; $a_4 = -\frac{1}{6}$;

for $\sum \frac{1}{x^5}$, $a_1 = 0$; $a_2 = \frac{1}{4}$; $a_3 = -\frac{1}{3}$; $a_4 = \frac{11}{24}$;

for $\frac{1}{3} \sum \frac{1}{x^3} + \frac{1}{5} \sum \frac{1}{x^5} + \frac{1}{7} \sum \frac{1}{x^7} + \dots$

$$a_1 = \frac{1}{6}; \quad a_2 = -\frac{1}{30}; \quad a_3 = \frac{4}{5 \cdot 7 \cdot 9}; \quad a_4 = -\frac{1}{3 \cdot 5 \cdot 7}; \quad a_5 = \frac{32}{2310};$$

and if we require the sums of the inverse odd powers, starting at $x+1$ instead of x , the same coefficients are needed, but $x(x+1)$ takes the place of $x(x-1)$, and now x may be any positive number.

Fresh-Water Biological Station.—*Report of the Committee* (Prof. F. E. FRITSCH, *Chairman*; Prof. F. BALFOUR BROWNE, *Secretary*; Dr. B. M. GRIFFITHS, Dr. GURNEY, Prof. H. S. HOLDEN, Dr. W. H. PEARSALL, Dr. E. S. RUSSELL, Mr. J. T. SAUNDERS) *appointed to consider the means to be adopted for the establishment of a suitably equipped Fresh-water Biological Station.*

THIS Committee has held three meetings for the consideration of the object for which it was appointed, and it has decided that the best means for attaining that object is the formation of a British Fresh-water Biological Association.

Steps have now been taken by those interested in the subject towards the formation of such an Association, which, however, is outside the work of this committee, which has now completed its work.

Stresses in Overstrained Materials.—*Report of the Committee* (Sir HENRY FOWLER, *Chairman*; Mr. J. G. DOCHERTY, *Secretary*; Prof. G. COOK, Prof. B. P. HAIGH, Mr. J. S. WILSON).

THE first meetings of the Committee were devoted to general discussions of the problem, and the best method of investigation.

The following programme of work was finally approved, and is in progress:—

1. An investigation of the stress-strain relation beyond the yield point, and an examination of any work already done on this subject.
2. A theoretical investigation of the stress and strain distribution beyond the elastic limit or yield point, in bodies of relatively simple geometrical form, *e.g.* simple beams, thick tubes, &c.
3. Experimental verification of the above examples.
4. A paper on the effect of overstrain in producing 'triple tensile stress' or 'fluid tension' (*i.e.* the reverse of fluid pressure), and the effect of such stress in producing fracture.
5. General papers discussing the application of the foregoing theories and experiments to practical problems in the light of experience.

The committee have co-opted Prof. G. Cook, D.Sc., and he has expressed his willingness to serve.

The committee ask to be reappointed for another year, as the work is still in its initial stages. The terms of reference were wide, and much time was spent before the above programme was approved.

No part of the grant has been spent this year, but it is hoped that the grant may be continued next year.

Sumerian Copper.—*Second Interim Report of Committee* (Mr. H. J. E. PEAKE, *Chairman*; Mr. G. A. GARFITT, *Secretary*; Mr. H. BALFOUR, Mr. L. H. DUDLEY BUXTON, Prof. GORDON CHILDE, Prof. C. H. DESCH, Prof. H. J. FLEURE, Prof. S. LANGDON, Mr. E. MACKAY, Sir FLINDERS PETRIE, Mr. C. LEONARD WOOLLEY) *appointed to report on the probable source of the supply of copper used by the Sumerians.*

(By Prof. C. H. DESCH, F.R.S., University of Sheffield.)

The grant made at the Glasgow Meeting has made it possible to employ Mr. E. S. Carey on the work of analysis since the beginning of last session. A variety of material has been examined, but the bulk of the specimens from Ur have not been received in time to include the results in this report. The specimens from Mohenjo-Daro, which were analysed numbered 64, most of which were of copper containing no more than traces of nickel. Twenty of them, however, contained appreciable quantities of nickel, the highest value found being 1.49 per cent., whilst 0.3 per cent. was more usual, the proportion thus being similar to that found in specimens from Mesopotamia. Nine of the specimens proved to be bronze, with tin ranging from 5.6 to 19.1 per cent., those rich in tin containing little or no nickel. The specimens from the 1927 excavations were richer in nickel than those found in 1926.

A parcel of specimens from the grave of Queen Shubaid at Ur was received. A bronze bowl, of which many fragments were found, contained 8.3 per cent. of tin and 0.51 per cent. of nickel. Silver fragments from the same source were found to contain a small proportion of gold. These specimens show the laminated structure of corroded bronze and silver objects very well, and an investigation is in progress, the object of which is to determine the mechanism of corrosion, in order to decide as to the extent to which analysis of a completely corroded object may be taken as indicating the composition of the original metal. This investigation, on which a fuller report will be made later, involves the preparation of micro-sections as well as chemical analysis.

Nickel in quantities ranging from 0.006 to 0.21 per cent. was found in a series of six tin bronzes from the 1928 work at Kish, the tin varying from 3 to 13 per cent. A small fragment included in the original batch of material received from Miss Bell gave tin 3.27 and nickel 0.54 per cent. Small specimens from the First and Third Egyptian dynasties from the Ashmolean Museum yielded only traces of tin and nickel.

Twenty specimens were received from Sir Aurel Stein, mostly from Makran. These were of very variable composition, the tin ranging from 0 to 27 per cent., and nickel being absent or only present in traces except in one copper specimen, which contained no less than 1.77 per cent.

Among other objects some small rings from Secunderabad, India, have been analysed. One, weighing 0.042 gramme, consisted of pure gold, whilst another, white in colour, was of electrum, containing 28 per cent. of gold.

A copper slag from Chrysocamino, Crete, received from Mr. O. Davies, was free from nickel, and completely similar to Roman copper slag from Spain.

A small double axe from Southern Thessaly was too thin to be drilled for analysis without spoiling it, so a spectrographic analysis was made by Mr. D. M. Smith, by the kindness of Mr. Twyman, of Messrs. Adam Hilger, and of the Non-ferrous Metals Research Association. The results showed:—

	per cent.
Antimony	0.1
Arsenic	0.5
Bismuth	0.005
Iron	0.15
Lead	over 0.5
Nickel	0.06
Silicon	0.1
Tin	over 1

(The spectrographic method unfortunately breaks down for the tin analysis, this metal being present in large proportion. It is hoped that this difficulty will be overcome.)

The subject of early iron objects has not been overlooked, the statement having been recently repeated that iron was smelted as early as 3000 B.C., in spite of the evidence that such early iron objects are of meteoritic origin. Scraps of the well-known iron ingot, found in the palace of Khorsatad, were received from Mr. G. A. Wainwright, of Cairo, and were found to contain neither nickel nor manganese. An iron fragment included in the batch received from Miss Bell and marked 'not later than 600 B.C.' also contained no nickel.

I have been informed by Dr. John Evans that he has recently found copper ores containing both nickel and manganese in Sinai.

I shall be glad if the committee may be allowed to retain the unexpended balance of the grant.

Kent's Cavern, Torquay.—*Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern.* (Sir A. KEITH, Chairman; Prof. J. L. MYRES, Secretary; Mr. M. C. BURKITT, Dr. R. V. FAVELL, Mr. G. A. GARFITT, Miss D. A. E. GARROD, Prof. W. J. SOLLAS.)

IN the report of last year reasons were given for stopping work in the Vestibule of Kent's Cavern, and after due consideration, it was decided to commence this season's operations on January 7, in the Wolf's Cave. This is a chamber situated nearly north-west of the Vestibule, branching off from the intervening Sloping Chamber, and is 100 feet from, and vertically about 20 feet below, the entrances to Kent's Cavern.

The Wolf's Cave has a continuous western wall, which, as one of the Cavern's main walls, extends down the Long Arcade into the interior; its eastern wall commences where the chamber branches off the Sloping Chamber, and from that point to its N.W. end is 28 feet.

At 12 feet from the beginning of the eastern wall the chamber attains its greatest width of 14 feet, and there are three passages or openings through the wall into the adjoining Cave of *Rodentia*. The Wolf's Cave was dug into three times before our labours began—by Rev. J. McEnery between 1825-9; then by the British Association under Mr. W. Pengelly, in 1871-2; later by Messrs. Powe and Storrs about fifteen years ago. A quantity of material excavated had been left in the Cave by the latter, and a number of large bone fragments lined the borders of their old trench, and gave hope of good finds.

Since January 7 excavations have been carried out once a week, and after removing the disturbed material a trench was dug from wall to wall, inwards, about 20 feet long by from 3 to 4 feet deep in undisturbed Cave Earth, in the course of which it has been necessary occasionally to remove large blocks of fallen limestone in addition to a great quantity of smaller fragments incorporated in the Cave Earth. In this were found a number of rounded and angular stones of the Red Grit of the Lower Devonian, derived from the Lincombe Hill which dominates the Cavern Hill—many more than came to hand in the Vestibule.

The remains of the old granular stalagmitic floor, broken up by McEnery and by Pengelly, still adhere to the walls and give the datum line by which to work. Below this stalagmitic floor Pengelly excavated 4 feet; this season's work represents a further excavation from 3 to 4 feet deeper.

So far there have been no further finds of man's handiwork, and experience in other parts of the Cavern tends to show that the deeper levels of the Cave Earth contain few or none. Pengelly recorded five implements from the first, third, and fourth foot levels, but a minute piece of flint was all that was found. The dearth of implements at the lower levels in this chamber and in the Vestibule suggests that there was a time during the early Cave Earth period when man was not in the vicinity or when the Cavern was unknown to him.

However, it is proved that a great depth of Cave Earth is still in the Cavern, and that it contains the usual relics of the Cave Fauna. McEnery had observed that the bones inhumed beneath the stalagmitic floor of the Wolf's Cave were found jammed under the ledges and in the crannies of the walls, and under fallen rocks. Our

experience has corroborated this. Very few coprolites (and these only in the upper portion of the Cave Earth) have presented themselves; also, the small foot-bones of the Cave Fauna are equally scarce, but among these one diseased phalanx of bear, identified as such by Mr. Ogilvie and confirmed by Sir Arthur Keith, came to hand. This differs remarkably from general experience in the Vestibule where coprolites and foot-bones were fairly common.

In the Wolf's Cave, at these lower levels, horses' teeth exceeded greatly in number those of the hyena. In Pengelly's records of the number of teeth of the various cave mammals those of the hyena almost invariably stood highest, and in relatively diminishing numbers, those of horse, rhinoceros, deer, bear, and mammoth. The large bones were usually found in a very rotten condition.

The three lower entrances to Kent's Cavern discovered by Pengelly were vertically about 18 feet below the south entrance. But excavation is being carried out 20 feet below the south entrance and at 100 feet distant from it, so that water entering the Cavern, which at one or more times flooded it so severely as to break up the Crystalline Stalagmite and parts of the rock-like Breccia, must have found outlets, by very circuitous channels, that are much below the lowest entrances yet discovered. The Cave Earth has shown no signs of stratification anywhere. Up to now digging has been done from the centre of the Wolf's Cave towards its terminus and downwards, but it is proposed in the future to work from the centre towards the Sloping Chamber. It is desired to find the Crystalline Floor, if it exists, and the underlying Red Grit basement deposit known as the 'Breccia.'

Thanks are tendered to many persons for their assistance in sorting and digging, among whom are the Rev. H. B. Hunt, Rear-Admiral and Mrs. O'Dogherty, Professor Hemmy, Messrs. G. C. Spence, and Mrs. Currey, Miss James, and the Misses Dick, and special thanks are due to the proprietor of the Cavern (Mr. Powe) for his generous aid on all occasions.

[Signed by the Excavators :—

F. BEYNON ; ARTHUR H. OGILVIE.]

Note on Operations outside the Entrance to Kent's Cavern, 1928-9.

During the winter of 1928-9 the proprietor of the Cavern had occasion to clear away a portion of the talus outside the main entrance, for the purpose of erecting a kiosk. The soil excavated was used for garden purposes, and to procure this the material was put through a sieve. As careful a watch as was possible was given to the progress of this excavation, and the proprietor himself watched the work, which was done, in the main, by himself.

The area concerned covered about 10 feet by 10 feet and ultimately a section 5 feet high was revealed, but nothing came to hand except one or two unidentifiable fragments of rather greyish bone, too light in weight to be regarded as of very great antiquity. The make-up of the deposit was a mixture of limestone fragments, large and small, with much dark earth or humus, and the whole appears to be a comparatively recent accumulation brought into position by the ordinary processes of denudation of the escarpment and its plateau.

The excavation did not proceed below the level of the sill of the Cavern entrance.

[Signed :—H. G. DOWIE.]

The Committee desires to be reappointed without grant.



Breeding Experiments on Plants.—*Report of Committee* (Sir DANIEL HALL, K.C.B., F.R.S., *Chairman*; Mr. E. M. MARSDEN-JONES, *Secretary*; Dr. K. B. BLACKBURN, Prof. R. R. GATES, Dr. W. B. TURRILL, Mr. A. J. WILMOTT) *appointed to carry out breeding experiments as part of an intensive study of certain species of the British Flora.*

RESEARCH aided by the grant of £50 made at the 1928 meeting of the Association is proceeding with British species of *Silene*, *Centaurea*, *Saxifraga*, *Ranunculus* and *Anthyllis*.

Silene.—Work is being extended in all directions and will take some seven or eight years to complete, at least. A paper (the second of a series) has been published in the *Kew Bulletin*, 1929, p. 33, and another (third of the series) has been sent to press.

Centaurea.—A great deal of work is in hand and will take a good many years to complete. It is hoped to write up the first paper at the end of this season's work. Last year over 1,000 plants were scored in the breeding ground, and this year about 1,500 will be ready for scoring and describing.

Saxifraga.—A preliminary account of genetical and cytological results has appeared in *Nature*. A full account, illustrated, is nearly ready for press, and will be sent, probably, to the *Journal of Genetics* as soon as the F₃ generation plants have flowered and have been scored. Tetraploidy and problems of species hybridization are chiefly engaging attention.

Ranunculus.—A preliminary abstract of cytological discoveries appeared in *Nature*, March, 1929. A fuller paper, illustrated, was sent to the *Journal of Genetics* in April. Work has to be continued on the genus for several more years. Problems of sex and colour are chiefly engaging attention.

Anthyllis.—Work is proceeding on colour inheritance and on sub-species hybridization.

Finance.

Grant £50. Up to date £17 17s. 6d. has been spent, entirely on wages for labour connected with breeding work on the genera mentioned above. Vouchers for this amount have been forwarded.

Leave is requested to retain the unexpended balance to cover part of the expenses connected with the carrying on of the experiments over another year. These are in full operation, and the expenditure on labour (for digging, moving, weeding, watering, &c.) is increasing.

Educational Training for Overseas Life.—*Report of Committee appointed to consider the Educational Training of Boys and Girls in Secondary Schools for Overseas Life* (Sir JOHN RUSSELL, *Chairman*; Mr. C. E. BROWNE, *Secretary*; Major A. G. CHURCH, Mr. H. W. COUSINS, Mr. T. S. DYMOND, Dr. VARGAS EYRE, Mr. G. H. GARRAD, Sir RICHARD GREGORY, Mr. O. H. LATTEr, Miss McLEAN, Miss RITA OLDHAM, Mr. G. W. OLIVE, Miss GLADYS POTT, Mr. A. A. SOMERVILLE, Dr. G. K. SUTHERLAND, Mrs. GORDON WILSON).

THIS Committee was appointed in 1923 under the Chairmanship of the late Dr. H. B. Gray. Its first objective was to ascertain what provision existed in the Secondary Schools of Great Britain for the 'Educational Training of boys and girls for Overseas life.' The inquiry arose from the observation that, although boys on leaving school were finding it more and more difficult to obtain suitable situations in offices and works in the home land, few were found to go overseas. In spite of the tempting offers by the Dominion Governments of free land and loans, it was noticed how few boys entertained the idea of a career in agricultural occupation, although it was evident that considerable numbers of the young men in banks and other offices are far better suited, from their character, and physical qualities, for the more vigorous and freer life on the land overseas.

The replies to a questionnaire sent to over 500 boys' schools and to 150 girls' schools supplied the bulk of the information contained in the report issued at Toronto in 1924. Inquiries were addressed at the same time to the Board of Education, Local Education Authorities and to Directors of Education in the oversea Dominions, as well as to various institutions such as the League of Empire, the Public Schools Employment Bureau, the Victoria League, and the Overseas Settlement Office. The replies received confirmed the idea that in most schools there is to be found a percentage of boys and girls whose capacities and interests would be better developed through practical studies than by the more academic work of Mathematics and Science; they further indicated a wide-spread opinion amongst headmasters in favour of a more practical type of school work for a large proportion of the pupils in their schools.

As a result of these inquiries the Committee came to the following conclusions:—

1. A demand exists on the part of the Overseas Dominions for boys of the right type with an agricultural bias, if not with training, and coincides with the home country's need of finding healthy employment within the Empire for a large number of her sons.
2. The public schools, and other large secondary schools of Great Britain send into the world every year a considerable number of boys and girls of the right type who are better fitted for an open-air than an overcrowded city life.
3. There has been no serious attempt in the majority of schools to meet this demand. Schools have hitherto provided only three avenues for subsequent careers—literary, mathematical and scientific—in some places only two. While this is sufficient for many boys, it does not provide for the more practical type, so that numbers find no outlet for their natural ability in that spirit of enterprise and adventure which Dominion life offers. They lack necessary guidance and experience.
4. The undoubted value of agricultural studies as a means of education has been overlooked in the past. Some schools have made with success the experiment of adding this new method for educating boys of the practical type. A few acres of land worked as a miniature farm, or as a number of experimental garden plots in the working of which boys take an active part, have not only been used for studying agricultural or horticultural problems but have provided material for working other subjects, particularly general science and mathematics. Such work encourages reading for a definite purpose, observation of natural phenomena, the keeping of records, and adds considerably to the appreciation of geography.
5. Experience shows that the school curriculum exercises an important influence in deciding a boy or girl's career. The school farm, or gardens, and associated studies of a practical nature would, therefore, bring to their notice the possibilities of a career on the land. It would give them some idea of agricultural activities and sufficient

contact with outdoor pursuits to enable them to decide whether they are fitted or not for country life.

6. The extension of such outdoor studies is not prevented by lack of land in many cases; 50 per cent. of the schools replying to the questionnaire have access to suitable land, but only 9 per cent. use it.

7. Development of a school curriculum in this practical direction for a section of a school needs encouragement because, while it would help to meet the requirements of the Empire, it is educational in a very wide sense.

8. There is need of some organisation to encourage overseas life, to link up the secondary schools with those societies which are able to look after the interests of prospective settlers overseas.

9. Whatever agricultural studies are undertaken at a school, it should be emphasised that the training is not intended to be technical such as is given in an agricultural college, and that they are in no sense to be considered a substitute for a definite apprenticeship on a farm, whether in Great Britain, or in one of the Oversea Dominions.

10. Manual training as an educational instrument has not hitherto received adequate recognition in the majority of schools. Comparatively few have facilities for metal work, and in the majority of these the work is optional, taken during out-of-school time, then usually in the lower forms only, and seldom co-ordinated with other school subjects.

11. There are a large number of schools eagerly awaiting the production of a practical scheme whereby the curriculum of the school can be broadened and rendered more adaptable to the demands of the Empire without sacrificing any of its educational breadth and efficiency. The chief obstacle to the production of a scheme lies in the lack of interest among those to whom such education might be offered. Many parents, however, would welcome a development of school activities in the direction of more practical studies in workshop, on the land, and in the laboratories, but their wishes are inarticulate, and, so long as there is no general expressed desire, the need is ignored. Public indifference to this need not only holds up progress, but indirectly prevents experiments by those who would like to attempt them.

The subsequent report for 1925 to 1928 presented fuller evidence of the growth of opinion in favour of agricultural and other outdoor studies in schools, together with some details of experimental courses that were being tried in this direction both at home and abroad.

In the present report for 1929 the Committee have brought together the chief results of their inquiry over the whole period:

1. *In Section I.* the Committee present some of the chief arguments in favour of a more practical type of education for a large proportion of pupils in secondary schools, stressing particularly the desirability of introducing into schools rural studies as a basis of practical knowledge and experience likely to help the pupil in its after life (p. 2).

2. *In Section II.* are discussed some of the difficulties in the way of introducing this type of work, viz.:

(a) the present examination system which attaches far more marks to book work than to practical work (p. 3).

(b) the short supply of teachers competent to undertake it (p. 4).

3. *In Section III.* are abstracts from reports issued by Departments of Education of the Oversea Dominions on the same subject (p. 4).

4. *In Section IV.* the general conclusions of the Committee (p. 10).

5. *In Section V.* the Committee has collected a number of definite schemes for practical work in schools known to be practicable and effective (p. 10).

SECTION I.

School Science.

In the past it has been claimed that physics and chemistry are of fundamental importance, and that without some knowledge of these it is impossible to understand physiological processes of plant or animal life. Hence the adoption, almost universally, of physics and chemistry as the science subjects for the curriculum of boys' secondary schools: and, on account of the crowded time table, these have been, for the most part, the only science subjects taught in boys' schools. Botany has been

the main staple for girls' schools with a modicum—usually a very inadequate one—of chemistry (see Report of Special Committee on Science in the School Certificate Examination in the Annual Report of the British Association, 1928).

In the opinion of the Committee physics and chemistry are both, at present, largely subordinated to working for examination purposes; that they have become largely technicalities, without any clear objective in the goal aimed at. The Committee feel that these studies at their best should be a means to an end, and not an end in themselves; that a broader view should be taken of the function of school science as a preparation for life and service; that life and action are the dominating features of existence, not words, facts, and theories.

It is admitted that in all schools there is a large proportion of boys and girls whose ability and mental capacity find their best expression in action, in doing and creating things, for whom the normal type of school work has little incentive and awakens little response, yet who in after life prove eminently capable of sustained effort, independent thought, self-reliance, and judgment. The type of school work required for these children does not fit in with the present examination system, and, as the belief is still prevalent that capacity can be measured only by the ability to learn through literary or mathematical studies, most schools make no provision for them. Fortunately there are schools where practical work has been made the basis of a good deal of the literary work, and where experience has amply proved the value of that system.

It is with this in mind that the Committee view with satisfaction the movement that has been gathering force during recent years to introduce biological studies into the curriculum; they feel that it accords with the policy advocated in their previous reports respecting agricultural studies which they believe will introduce, naturally and purposefully, most of the biological work that is possible in any ordinary school course, as well as much of the physical science necessary. The Science Masters' Association has had a small committee working on the same problem in order to meet a general request from some of its members for guidance in the teaching of agricultural science.

Rural Studies.

The original purpose of the Committee led them to investigate the possibility of including agriculture in the school curriculum. The evidence they have collected has gone far to convince them that rural studies have a much more extended use than that of simply preparing boys and girls for overseas life. If properly organised it has been shown they possess the highest cultural value, as well as a source of inspiration for much of the scientific work possible in schools.

Much misunderstanding of the claim of agriculture to be considered a proper study for school arises from a misconception of its aim, method, and content. Some reasons for its inclusion, and the interpretation to be given to the term rural studies as applied to schools are briefly stated below.

A sound education is the thing that matters most for the intending migrant. But no education is sound that does not provide some handwork, especially for those who can learn better through practical methods.

The Committee believe that in rural studies schools would possess an educational instrument of wide adaptability, affording intellectual material of the highest kind for the best intelligences, yet providing, through its practical nature, scope for the less endowed. They believe that in agricultural work and its associated activities the practical boy can be provided with the most suitable avenue for his energies. At the same time they feel that the chief purpose of these studies should be the use of environment for intellectual development, of outdoor life and interests for understanding the realities of life, and for inculcating an appreciation of the important rôle that agriculture has played, and must continue to play, in the affairs of men; and through related history and geography to use it for promoting an intelligent understanding of the growth of civilisation. They, therefore, would stress the following aspects of rural studies in support of the claim made for their inclusion in the curriculum of country schools at least:

(1) that the real use to which rural studies may be put is educational; that the farm and garden can supplement the laboratory or workshop for the study of physics, chemistry and biology; and are as necessary to science teaching as the ordinary laboratories and their apparatus:

(2) that the contact with life which rural studies bring gives purpose and reality to school work generally; they create interest and provide a rational basis for all branches of scientific inquiry:

(3) that these studies provide opportunities for a simple and natural approach to the physiological processes of life, and, when correlated with the teaching of geography and history, constitute a basis of instruction of far reaching importance:

(4) that rural studies further supply many opportunities for handwork of a very practical type, and so help to bring out latent capacities in this direction, which otherwise frequently go undetected and undeveloped.

Practical Work Essential.

In diverse ways a considerable body of experience is being gathered, both at home and abroad, which should in the near future indicate how these rural studies can be utilised to the best advantage in the interests of education generally, how they can be adapted to different types of schools, and how developed on a sure foundation for the benefit of all concerned.

One essential feature is the need for practical work on the land, which is as necessary to any course of rural studies as practical work in a laboratory is to chemistry. If agriculture were adopted as a subject for the First School Certificate Examination, it should not be treated as an entirely indoor study; rural studies without practical work out-of-doors lose most of their educational value. It is the contact with things, not words, that in this case counts for so much. The opportunity afforded by a school farm or garden for bringing most of the science work into close relationship with reality is extraordinarily useful. Such work gives purpose and life especially to

(1) the study of botany through the types of plants cultivated or occurring as weeds;

(2) the study of insect life—useful and injurious organisms that play such an important part in the cropping of the land;

(3) the study of elementary physics and chemistry, for school gardens can supply much of the material required for these subjects in the early stages.

The principle of giving to older boys and girls, say, from 15 years upwards the opportunity of studying animal life and land cultivation on the scale afforded by farm conditions has many claims for serious consideration.

An examination of the present situation indicates that schools already interested in rural problems are attempting to attack the problem along two lines. Some give their science a rural bias by making use of farm and garden for illustrations, and co-ordinating it with handicraft training by including practice in making things for outdoor operations. The bias is also to be found in the history and geography teaching. On the other hand, a few schools, with facilities for practical work on a farm, tackle more definitely agricultural studies, the pupils taking part in dairying, poultry, husbandry, &c. But the number of schools actually doing this is few, and the number of pupils taking the agricultural course in these is small. Only a few schools may be suitably placed for developing this more technical course. On the other hand, there is no doubt, given qualified teachers with an interest in rural studies, the majority of the secondary schools in the country could tackle the problem through science and handicraft and some other subject. The needs of the home, and the many interests of everyday life could be made the subject matter for workshop and science class purposes. The Committee feel that while some progress may be made in introducing definitely agricultural studies, it is in giving the curriculum a more practical bent that any great development must be looked for.

SECTION II.

DIFFICULTIES IN THE WAY OF A GENERAL ADOPTION OF RURAL STUDIES IN SCHOOLS.

The difficulties that lie in the way of a general adoption of Rural Studies in schools seem to be due mainly

(1) to the conditions and requirements of the present system of the School Certificate Examination;

(2) to an inadequate supply of properly qualified teachers.

(1) *Examinations.*

The Committee believe that the discouragement of practical studies in schools is incidentally due to the absence of sufficient provision in our present system of examination for a recognition of their value, and for an estimation of their efficiency. They are convinced that the existing conditions of external examinations exercise a much greater control over curricula and methods of teaching in schools than is realised by the community generally; and as that control is all in favour of a bookish and academic type of work, it follows that schools have little or no freedom to adopt a policy which does not accord with the demands of examiners.

'The examination system has now acquired such a masterful position in our educational world that what it does not encourage it tends to frustrate.'¹

Examining bodies generally do not sufficiently grasp the handicap which practical work places on candidates for the First School Certificate as compared with the simpler order of studies provided for other pupils, requiring only book and paper.

In connexion with the growing belief in the educational value of practical instruction it may be pointed out that at least three of the First School Examinations now include Handicraft in Group IV. In addition, the Committee are glad to note that the Secondary Schools Examination Council,² after consultation with the Board of Education, have decided that, 'as an experiment, two subjects from Group IV should be allowed to count in the examination held in 1929 and 1930 towards the five subjects required for a pass in the examination, the present requirements of a pass in each of the groups I, II and III being retained.' In the meantime the Council propose to explore the question further and to ascertain what subjects in Group IV should be allowed permanently to count for a certificate and what their content should be. Among subjects usually included in Group IV are :—Art, Music, Handicraft, House-craft, and Book-keeping and Shorthand.

The Committee hope that this report will lead to a reconsideration of requirements for the First Schools Certificate Examination that these may be so modified as to fall in with reasonable suggestions made to recognise all the educational activities of a school course, and especially those abilities of a practical nature exhibited by a very considerable section of the school population. Much might be urged in the interests of the boys or girls under consideration on the grounds that a capacity for doing and thinking in shape, in things, is at least equal to a capacity for memorising statements. School teachers are often well aware that these pupils could never pass the standard required in Latin or Advanced Mathematics, and yet they are not allowed to substitute a practical subject in which they would excel, simply because there is no machinery for measuring the quality of such work. Yet as far as their future is concerned it would be of incalculable value to them to have every opportunity of developing their natural gifts.

(2) *The Supply of Teachers.*

The educational value of rural studies, as in all other subjects, depends largely upon the way in which they are organised and presented to the pupils. It cannot, therefore, be too strongly urged that teachers are required who not only have technical knowledge, but also understanding of, and sympathy with the aspirations and possibilities for character-training, that lie behind these studies.

In common with all new educational developments the difficulty of introduction lies in the comparative fewness of teachers who possess the requisite qualifications. The slowness of adoption of rural studies is partly due to this, and partly to the numerous headmasters and headmistresses who do not appreciate fully the educational possibilities of practical teaching, and are unwilling to break away from the shackles of the traditional curriculum. A change in their attitude is a process that requires time, though sympathy on their part would accomplish much.

A suitable staff is the crux of the whole matter. The teacher required must have knowledge of agricultural conditions, he or she must be an enthusiast and someone of vision who can arouse the imagination and enthusiasm of boys and girls in their charge. To increase the supply Cambridge and other schools of agriculture should be approached, and a scheme devised to turn out a larger number of teachers trained and qualified for this particular work.

¹ British Association Report on Science in School Certificate Examination, 1928.

² 'Education in 1928.' Report of the Board of Education.

But it is in the schools eventually that such training, in the first place, must be looked for, and the vicious circle broken which, through the present academic system of the School Certificate Examination, precludes the full development of practical ability, and tends to discourage it in those who have it.

SECTION III.

RURAL STUDIES IN SECONDARY SCHOOLS OF THE OVERSEAS DOMINIONS.

The opinion held in the Overseas Dominions on the subject of rural studies in schools is in complete accord with the views expressed above. The following abstracts are quoted from memoranda sent in response to the Committee's inquiries.

CANADA.

ONTARIO.

A special committee appointed by the Minister of Education for Ontario, consisting of representatives of University Colleges, High Schools, Inspectors, and the Department of Education, recommended very drastic alterations in the curriculum and public examinations of the High or Secondary Schools of the Province. In his report for 1920 the Minister describes the situation as follows:

'The Agricultural Instruction Act of 1912 provided funds for agricultural education in the different provinces, applied first to rural schools only, but later successfully to suburban schools. In 1917 the scope of the grant was extended to urban schools. This aspect of the work has developed very rapidly, and as a result of such development a new view seems to be gaining ground, to the effect that much good might arise in the direction of a better understanding between city and country, and possibly, later on, many of the pupils now studying agriculture in the city schools may be led to take up their life-work in the country.

The Teaching Difficulty.—'The chief difficulty in introducing and in maintaining classes in agriculture in secondary schools is lack of qualified teachers. Courses are provided at the Ontario Agricultural College, covering two consecutive summers, of five weeks each. Because of the fact that agriculture is not yet a regular subject on the High School curriculum, summer courses are necessary. In many other respects these courses in agriculture for teachers are the most important and far-reaching of all the agricultural courses given in Ontario, because through the teachers they have much to do with the shaping of the minds of the rising generation in such a way as to develop a mental attitude more in harmony with rural conditions. Not only do these courses so direct the rural mind at an early age, and thereby produce lasting impressions, but they assist materially in showing how the farms may be made more productive, and therefore more profitable, thus providing the economic incentive necessary for a happy life on the farm.

'As the High Schools are the real source from which the teachers are derived, the influence of these schools is paramount in so far as the supply of suitable teachers may be concerned. By the term "High Schools" is meant all Secondary Schools, whether they be called Continuation Schools, Collegiate Institutes, High Schools, or Private Schools, carrying on High School work. The course taken in the High School is largely a determining factor as to whether the student eventually becomes a teacher or not, consequently one of the causes of the shortage of teachers has its roots in the course of study in the High School. And, because of the dominating influence of the University in its requirements for matriculation in the various branches of college work leading to a degree, the course of study in High Schools is shaped largely by the Universities. The language requirements for matriculation make so large demands upon the time of the pupil while in the High School that the student finds himself unable, for lack of time and energy, to carry on a course which includes agriculture or household science.'

Many of the recommendations were adopted and were in force in 1922. The inclusion of agriculture as an optional subject in place of physics and chemistry was one interesting feature of the new order. A four-year course of agricultural studies was drawn up for the High Schools of Ontario, and any student, if he desired it, given credit for this work for entrance to the University, the Normal College or the Ontario Agricultural College.

BRITISH COLUMBIA.

Agricultural Courses in High Schools.

'The value of agriculture as an educational subject, which develops the mind of the student by teaching him in terms of his everyday surroundings rather than in terms of the abstract and remote, is becoming more apparent each year. One-third of the present public schools' teaching staff in Langley are graduates of our High School Course in Agriculture, and by their ease of adaptation to the needs of the rural schools and interesting and practical methods of teaching the course in nature study and elementary agriculture have emphasised to a surprising degree the technical value of the instruction given in our High School Course.

'The feeling is growing amongst the people generally that if the education of to-day has any relationship whatever to the welfare of the people of to-morrow, then agriculture, both educationally and vocationally, is a subject that must not be neglected.

'The teaching of agriculture in "High Schools" is now well established in all the Provinces of the Dominion, and is meeting with greater success year after year. This is partly due to the fact that better-qualified teachers are being employed than formerly, resulting in more efficient instruction, and partly to a better understanding of the real nature and value of the work on the part of parents and school authorities.

'The regular two-year course in agriculture is now carried on in twelve High Schools and one Superior School in the Province, the total enrolment for the year being 510, an increase of fifty-three over last year. The two-year course in agriculture is given in Grades X. and XI., and in most cases is preceded by a course of general science in Grade IX. This introductory course in science has been found advantageous as an introduction to the study of agriculture as well as to other branches of science, and is usually taught by an agricultural instructor.

'The offering of courses in agriculture in city High Schools was looked upon at first as a rather doubtful experiment, and no doubt many were ready to regard it as rather fantastic and quite inappropriate as a subject of study in such schools. Those, of course, who so regarded it were labouring under a wrong impression as to the character and purpose of these courses—the impression that only those boys who were definitely preparing to go on the land to earn their living could possibly be interested in such courses or could hope to be benefited by them. After six years' experience in the City of Victoria and three in New Westminster, and an even longer period in smaller cities in the Province, there is little room for doubt as to the beneficial character of the work in those cities. Spasmodic efforts are made from time to time by Boards of Trade and other organisations to promote mutual understanding and good-fellowship as between the rural inhabitant and the dweller in the city. This, of course, is highly desirable, but in no way can it be as soundly and permanently established as by giving to city-bred boys and girls the opportunity to study at first hand the essentials of food production and of rural economics. City boys and girls have responded in a very satisfactory manner in every case where an opportunity was offered them to include the study of agriculture in their elective courses. We should have more agricultural specialists in our city High Schools.

'We must all, however, confess to a certain amount of surprise at the remarkable degree of success which has attended the study of agriculture by the girls in our various High Schools. In the classroom, in the experimental gardens, and in the judging pavilion they have more than held their own, for they have succeeded on more than one occasion in carrying off the premier honours in examinations and in agricultural judging competitions in which more boys than girls participated.

'The High School agricultural classes are steadily growing in size and the work is gaining in popularity. Not only is this shown by the increasing number of students electing agriculture, but also by increasing interest manifested by the ratepayers themselves. It is gratifying to know that even during a period of retrenchment, due to poor prices for crops, it was not thought advisable to discontinue the teaching of agriculture. This attitude is in a measure due to the realisation that teaching through and about the daily life of the community is sound pedagogy.

'It has been established by years of observation that even the most promising boys who leave the Old Land to go into rural life and work in the Overseas Dominions have not always succeeded, and have had to learn, often by disheartening experience, many things fundamental to such life and work which they might readily have learned in a large measure in Secondary Schools at home, had they been but given the

opportunity. Boys of good physique who are mentally keen and of good character are the lads for overseas, and these should be given special training.

'It is a matter of common knowledge that a large percentage of the men and women from the Old Land who come to Canada either come directly to the cities or soon gravitate in that direction. If this condition is to be changed so that our rural districts are to become more largely populated as the result of immigration something must be done to develop a genuine interest in agricultural science as applied to the various branches of farming amongst young people of the Old Land before they leave school or before they arrive in Canada. This can be done either by having these young people attend special schools of agriculture for limited periods or by making the study of agriculture part of the regular course in Secondary Schools covering two or more years. The latter is the method now being followed in some of the Provinces in Canada, and particularly in British Columbia. As agriculture itself is a great composite science, it follows that almost all branches of so-called pure science can and should have some reference to it. This is particularly true of the sciences of geology, meteorology, chemistry, physics and biology—sometimes referred to as basic sciences in relation to agriculture. To those may now be added rural sociology and economics.

'The mere use of appropriate subject-matter for classroom lessons, however, is not sufficient to ensure a real and abiding interest in rural life and occupation. Genuine first-hand knowledge and acquaintanceship with soils and soil constituents, with cultural methods pertaining to field, orchard, and garden crops, and some actual experience in the care and management of poultry and live stock are essential if more than a fancied or fictitious interest is to be established. This can all be included in a good general course of Secondary School grade in all but the largest cities.

'It is difficult, even under the most careful instruction, for young people to form a correct mental picture of a new country or fully to appreciate the conditions to be met with in such a country, not having seen it. It is important, therefore, that every effort be made to supply reliable information to all young people relative to the British Dominions, and particularly to that particular Dominion to which they may purpose going. The all-important subjects which will be of service in this connexion are geography, history, and literature. Young people looking towards Canada, for instance, as their prospective home should give special attention to Canadian geography, to Canadian history, and to the works of Canadian writers both in prose and poetry. The use of the stereopticon and moving-picture machine is most important in helping to make more real scenes and events relative to the new country. Illustrated lectures on the British Dominions overseas delivered here and there in Secondary Schools in the Old Land would be of advantage. Magazines and agricultural papers published overseas should be on file in the larger schools and, if not already established, there might well be a central bureau of information, say, in London, where all teachers could apply for special information relative to overseas topics.

'Having in mind that the rural problems in the Overseas Dominions are concerned with the welfare of men and women alike, it would be the greatest of folly to attempt to plan a special course of instruction for boys who might be looking forward to a life in a new country, and not do something similar for girls. Experience in a dozen Secondary Schools in British Columbia, where agriculture as an optional subject has been taught to boys and girls alike, goes to show that the 'teen-age of girls have done quite as well in examinations and also in the practical work undertaken as have the boys. The elements of agricultural science as well as a good working knowledge of household science for girls are almost essential to successful and contented living in rural homes. This does not mean an influx of farmerettes is wanted. It does mean that successful rural homes depend to a large extent upon the ability, training and managerial skill of the housewife.'

Method in Agricultural Studies.

'The text-book method of instruction in agriculture, which has repeatedly been tried in years past in some parts of Canada and which has always failed and must always fail, has been ruled out in British Columbia. The principle of direct instruction and knowledge at first hand are followed throughout. Every High School offering courses in agriculture is equipped with a good working laboratory classroom where various lines of laboratory experiments and the direct examination of agricultural

material can be carried on. This is supplemented by having agricultural experiment grounds or gardens convenient to the school where various aspects of gardening, field husbandry and horticulture are dealt with from year to year, the students themselves with their instructor doing practically all the work. Class excursions to the best farms in the community in which the school is located, for the purpose of observing and discussing the methods followed in the various lines of farm practice, are frequently conducted. The individual students carry on a well-regulated scheme of home projects in agriculture having direct bearing upon the work taken up at school. In some instances the home projects are standardised and conducted under rules involving a competition in the production of garden or field crops or the raising of young animals or poultry. In such cases the home projects are made the basis of organisations now widely known as Boys' and Girls' Agricultural Clubs. In computing the standing of the students in agriculture at the end of the year, 50 per cent. is based upon a uniform provincial examination and 50 per cent. upon term work, the latter being determined by the instructor.

'Students who elect agriculture for junior matriculation or for the teachers' High School Course, and who afterwards complete the Normal Training Course, are granted a special diploma in rural science or elementary agriculture. The agricultural option has obvious advantages for teachers who afterwards teach in rural or village schools.'

Main Purpose and Objective.

'Boys taking the High School course in agriculture are not regarded as prospective farmers, and no special effort is made to induce them to go into farming as their life-work. The study of agriculture as conducted in our High Schools is regarded as a valuable and almost essential part of a good liberal education. Its interests are healthful and its influences positive and beneficial. It calls out personal initiative and helps to develop self-reliance and resourcefulness. It gives new interest and new meaning to other science studies by affording innumerable examples of science applied. It affords one of the best avenues through which to approach the great biological secrets and mysteries of plant and animal propagation and the laws of heredity. It develops certain skills incidental to scientific experimentation and to approved practices in farming and gardening.

'In all these aspects it is essentially and primarily educational and suitable alike to girls and boys, regardless of the particular vocation which each may ultimately choose. On the other hand, it may be of great value in setting up new standards and new conceptions of the true nature and meaning of agriculture in the minds of these young people, as a result of which they may be drawn to choose farming as an occupation.

'When such an educational and scientific basis has been laid for the farmer of the future the quality of our rural citizenship will advance, and not till then.'

SASKATCHEWAN.

Abstract from a Report of Director of Education.

Introductory.

'The field of activity known as Agricultural Education may be roughly divided into two sections or divisions, the chief emphasis in the one being placed on subject-matter or content, in the other on educational values. The former is frequently designated Education in Agriculture, and includes all forms of vocational training in agriculture whether conducted in High Schools or College or through extension courses. The other, which is quite properly called Education through Agriculture, embraces the agriculture courses in Elementary and High Schools as well as the project work carried on by Boys' and Girls' Clubs.

'Agriculture as a subject of study in the school grades requires no defence. It is now almost universally accepted as a regular feature of school routine, although frequently found under another name. There is still a difference of opinion as to its content—should it be more of the nature-study type, or should it assume the form and methods of science? This problem must ultimately be settled by a consideration of the child rather than the subject, and the work must be graded to suit the mental possibilities of the pupils.'

Elementary and Secondary Schools.

'(a) A course of nature study is outlined for the lower grades of the Elementary Schools, and serves as an introduction to geography; a more advanced course in nature study serves as elementary science in the middle grades. A course in agriculture based on nature study is prescribed for the top grades, and is designed to provide opportunity for the organisation of the information gained by the pupils through direct observation.

'(b) Agriculture in the High School presents another phase of the problem. What should be the nature of such a subject? Clearly it must cease to be of the nature-study type, and assume a more scientific form. After many trials and readjustments it has been incorporated as an integral part of the science course of the first two years, and is compulsory for all students. In the third year it is an elective subject on a par with physics, chemistry, or home economics, i.e. it is merged with chemistry, physics, and biology in the first two years, but emerges again in the third year on a par with physics and chemistry as an optional subject for examination.

'Thus we have nature study, which aims to make the fullest use of the environment of the pupil, occupying the basic position. And since most of the population live on the land, and the rest are directly dependent upon the success of farming operations, agriculture is the predominant factor in that environment, with the result that it colours and enriches the whole content of the nature study.'

Aim.

'The instruction should be such as to bring the life and interests of the school more closely into touch with the home life of the pupil. His capacity to enjoy life should be increased by training his powers of observation, and by developing a sympathetic acquaintance with the things of nature. Through the practice work which must necessarily accompany proper instruction in this subject, useful information will be gained, and a respect for farm labour developed. The work should go far to promote the qualities that make for good citizenship, such as consideration for the rights of others, and the principles of co-operation in seeking the common good.'

Method.

'The method employed should place the child in contact with natural objects with which he is familiar, and lead him to seek his information from them by the use of his senses. The teacher should direct and assist rather than instruct. He should find out what is known, and direct to the unnoticed and unknown. He should gather from the pupil the "what" and the "how" of phenomena and lead him to seek the "why." The expression of what has been observed may take the form of oral or written composition, drawing, modelling, or any other form appropriate to the matter.'

Content or Syllabus

The outline of the work is as follows:—

First Year—Part of Science Course.

'Soil water: experiments to find soluble matter in soil, to measure rainfall; consideration of annual precipitation and of conservation of soil moisture.

'Seeds: structure of the seed and seedlings of the common plants of the district, such as pea, bean, corn, wheat, oat, weeds; dispersal of seeds; germination; conditions necessary for germination; seed-testing.

'Experiments to show: (a) test for carbon dioxide; (b) that carbon dioxide is given off during germination; (c) that seeds contain starch.

'The plant: forms and functions of roots, stems, leaves, flowers and fruits of the common plants of the district, such as pea, bean, corn, wheat, oat, barley, carrot, turnip, weeds.

'Experiments to illustrate osmosis, transpiration, respiration, starch-making and constituents of plants, so as to bring out the relation of the plant to light, water and heat.

'Observation of the life-history, habits, and control of common insect pests, such as house-fly, grasshopper, mosquito.

'Bacteria: simple descriptive lessons on the activities of bacteria in decay, in roots of plants, in milk and in the home generally; action of yeast.'

Second Year.

'Propagation of plants: pollination, fertilisation, cutting, grafting, budding.

'Farm crops: importance of good seed, rotation of crops, eradication of weeds, prevention of plant diseases, destruction of insect pests, harvesting and storage. Production of wheat and potatoes.

'Farm animals: horses, cattle, hogs, sheep and poultry, care and management.

'A study of the cabbage butterfly, the cutworm, the spider, the bird, the gopher.

'The soil: origin and formation, kinds, weight, texture, colour, porosity. Elements of plant food. Soil water, soil air, soil heat, soil organisms, soil fertility. Tillage and use of farm implements.

'Farm management: elementary knowledge of the common business transactions of the farm; crop growth; cost of production, of marketing, or operation; buying and selling; farm labour.'

Third Year.

'Review of the work of the first and second years.

'Consideration of those plants or parts thereof grown for food, clothing, and for building and manufacturing purposes: (a) in the immediate locality; (b) elsewhere in the Province and other parts of Canada; (c) imported into Saskatchewan from outside Canada. Plants grown for ornamental purposes, shelter belts and hedges, annuals, biennials, perennials. Propagation of plants, improvement of plants in quality and quantity, selection of plants and seed, specific reference to wheat, oats, etc.

'Identification of at least ten noxious weeds; study of root, stem, leaf, flower, seed and seed dispersal, with special reference to best means of eradication.

'Farm crops: alfalfa and western rye grass, wheat and oats, potatoes and turnips, onions and lettuce, rhubarb and celery, currants and strawberries, spruce, geranium, crocus.

'A study of plant foods and fertilisers with reference to above crops.

'Consideration of animal products: for food and man, for food for animals and for clothing: (a) in immediate locality; (b) elsewhere in Saskatchewan from outside Canada. Study of types of breeds; feed and food rations and ratios; care and management, improvement and selection, of cattle, horses, sheep, pigs, poultry.

'Life-history and control of (a) one or more common plant diseases, *e.g.* potato blight, cereal rust; (b) one or more common insect pests, *e.g.* cutworm. Types and uses of farm implements, cost, care and housing of same with a view to economy. Co-operation in buying and selling, farm accounts, cost of production, etc., planning and equipment of home and home surroundings. Study of local rural organisations and their work.

'The ultimate success of any phase of school work depends upon the quality of the teaching, hence the necessity for better and more thorough professional training of teachers. By its very nature agriculture cannot become as thoroughly standardised as subjects such as arithmetic, and therefore will suffer at the hands of the poorly trained instructor. The necessity of definite training in agriculture in the Normal Schools has long been recognised, and for many years it has been a regular feature of the course. Consequently every student attending Saskatchewan normal classes receives some instruction in nature study and agriculture. Further, by means of summer courses, institutes, conventions, and personal advice and assistance, the teachers in the field are afforded opportunity to become more efficient in their task of dealing with this somewhat difficult subject.

'In conclusion, it may be stated without any hesitation that there is a gradual improvement in the teaching of agriculture from year to year. Its real place of importance is becoming better understood. There remains, however, much to be done before anything approaching ideal results can be achieved. And, further, there remains to be exploited the great field on the border-line between education through agriculture and vocational agriculture, especially among 'teen-age boys and girls.'

• AUSTRALIA.

VICTORIA.

The Director of Education reports that regular instruction is given in agriculture and horticulture to all boys and girls in the rural schools of Victoria of ages 12 to 16. The work is carefully organised and systematically carried out under skilful supervision.

Where possible the agricultural work is linked with laboratory work for dealing with problems concerning the soil and its physical and chemical properties. The boys carry on many of the farm operations, but only to a small extent. It is mainly for educational purposes, and not as a sufficient training in actual handiwork.

Manual training is commenced at the age of twelve and forms a definite part of the school curriculum.

Considerable interest is taken in this work by parents and members of Agricultural Societies and Farmers' Associations.

Agriculture or horticulture is a compulsory subject in the curriculum of the rural schools. It commences in the elementary schools and is continued in the secondary schools. The course combines both mental and manual training. The mental development of the scholar is considered of greater educational import than the acquirement of practical skill. The aim is in the direction of promoting initiative and a spirit of independent investigation. Lessons on the great basic principles of plant cultivation are common to every course.

The course follows a carefully prepared system, including :—

(1) Instruction in the elementary principles of agriculture and horticulture.
(2) School experiments illustrating the principles underlying successful field operations.

(3) Outdoor work in the school experimental plots and in the school garden. Every school has a garden.

(4) Extension of outdoor work to home projects.

(5) Record work in notebooks.

All this is done in the Elementary School. When boys pass on to secondary education in Agricultural High Schools the syllabus in agriculture is, of course, considerably extended. It includes farm operations, farm machinery, selection and care of stock, etc.

In the Higher Elementary and in the Secondary Schools woodwork or farm carpentry is taught. This includes the study of useful timbers and a small amount of forestry. The girls may at the age of twelve years proceed to a School of Domestic Arts, where, in addition to the usual course of English and mathematics, instruction is given in cookery, needlework, dressmaking, millinery, laundry, housewifery, first aid, personal hygiene, and home nursing. The objective is to train girls to be efficient home-makers. These schools are popular. The mothers of the girls frequently send letters of appreciation to the Education Office. The course is free and may cover a period of three years. The girls may proceed to a higher course of domestic economy or to a High School for academic studies. The courses of training in agriculture and in domestic arts have proved to be educational to a high degree.

There is a distinct advantage in allotting part of the school time to a plan of work outlined above.

In a report on the Ballarat Agricultural High School Sir R. B. Greig in 1910 said :—

'This school is one of a number which have been organised in Victoria since 1906 for the further education of boys and girls, on the assumption that the majority of the boys would become farmers and the majority of the girls would proceed to higher institutions for training as teachers.'

' Aim of the School.

'1. To give boys such education as will direct their interest specially towards the land as an excellent means of gaining a livelihood, and, further, to afford the practical experience and scientific training necessary for success.

'2. To magnify agriculture as an occupation and a profession, so that the boy may leave the school as an interested labourer, or for further study and practice on an experimental farm, in an agricultural college, or at the University.

'3. To provide a central institution for the dissemination of agricultural information by evening lectures, conferences, or literature.

'4. To superintend the Government experimental plots, and to record and interpret the results.

'5. To provide a summer school in agriculture for Primary School teachers.

' Conditions.

' The pupils must be 14 years of age and show satisfactory evidence that they are qualified to profit by the course of study in each school. Pupils are not resident at the school, but boarded in the neighbourhood under careful supervision. Fees £8 to £10 per annum.

' Syllabus of Instruction.

' The syllabus of instruction includes the ordinary school subjects to the extent to which they are carried in the ordinary grammar school, although the contents of the subjects are varied and one-third of the pupils' time is given to agriculture. Sloyd, farm handicraft, and drawing are prominent in the curriculum. The science subjects are chemistry, physical geography, and climatology; the agricultural science in the syllabus is elementary botany and zoology, and from my observation the methods, which are chiefly experimental and with a strong agricultural basis, are very efficient. The "principles of agriculture" deal with soils, particularly Victorian soils, rotations and cultivation of crops, irrigation, feeding and general management of farm livestock, ensilage, first-aid to animals, and the general principles to the valuation of fertilisers, milk and cream, farm crops and animal products.

' The farm attached to the school is worked in such a way as to illustrate the principles laid down in each section of the syllabus; it is used as a centre of experimental work, and where it adjoins the school, as at Ballarat, the boys are constantly at work on it. When it is at a distance, the pupils spend a certain number of hours there each week and sleeping accommodation is provided, so that a limited number may, in turn, see and take part in the whole round of the farm work. As none of the farms are more than five years old, much of the preliminary work of building, clearing, draining, road-making, etc., has been done by the pupils; and at Ballarat the grounds surrounding the school have been laid out, planted, and kept in order by them. The High Schools exhibit produce, experimental material, and students' work at the show of the Royal Agricultural Society at Melbourne; the competition is very keen and, no doubt, is one of the factors in stimulating the remarkable interest the boys take in the farm.

' I have dwelt upon the agricultural side of the school, but it must be kept in mind that most of the girls and some of the boys are hoping to be teachers, or to follow pursuits other than agricultural, and their education is therefore on more general lines, and includes languages, and, in the case of the girls, domestic economy. Mr. Frank Tate, the Director of Education for Victoria and the chief promoter of these schools, says that the reacting effect of the agricultural side upon the ordinary traditional subjects is great and satisfactory, and, encouraged by these results, the Department intends to develop High Schools with a commercial and an industrial side on precisely similar lines. Certainly I have never seen more energy and interest than was displayed by those boys and girls when observed at work. Mr. Tate says, further, that the fault of the vocational school in the past has been to make it narrowly technical—a pregnant opinion.'

QUEENSLAND.

The Under-Secretary to Department of Public Instruction, Queensland, reports as follows:

' Recognising the value and the necessity of vocational training during the latter years of school life, the Department of Public Instruction (Queensland) has, during recent years, amended the previously established courses of primary and secondary instruction. Though there remains a direct line connecting Primary, Secondary, and University activities, pupils may diverge at certain points to take up work which is preparatory to vocational employment. The points of divergence lie (a) at or just before the completion of the Primary course, (b) half-way through, or (c) at the end of the Secondary course. Generalising, schools or classes giving instruction in commercial subjects are provided in the larger commercial centres; technical instruction in towns where secondary industries are flourishing or expanding; elementary agricultural schools (called in Queensland "Rural" schools) at the centres of important agricultural (including dairying) districts. In all these special schools the general education of pupils absorbs the greater part of school hours, but vocational subjects are substituted for the purely academic during the remainder. The under-

lying principle which is being followed through the experimental stages is, "Adapt the instruction and training to meet the probable necessities of pupils in after-school life."

'Regarding agricultural education, though the introduction of formal studies bearing more or less directly on practical agriculture does not commence until pupils have attained at least a competent knowledge of the principal rudiments (the three R's), pupils in the lower classes of elementary schools have had their interest aroused in nature study, school gardening operations, and, in many country schools, in milk and cream testing.

'In the "Rural" schools (virtually continuation schools) the programme adopted by the Department is as follows:—

'Upper-class children whose circumstances or inclinations or capabilities do not permit of them proceeding to the ordinary Secondary Schools take up the study of elementary agricultural science and the practice of agricultural operations; they are also employed in learning manual arts, such as carpentry, leather-work, metal-working (including plumbing), fruit-packing. Girls are instructed in domestic arts and science—cookery, laundry-work, dressmaking and millinery, preserving fruit, etc. Both boys and girls learn how to keep household accounts and gain a knowledge of such ordinary commercial transactions as they may be called upon to execute in their future vocations.

'The young students are not called upon to prepare for any set examinations. The stimulus lies in the obvious connexion between their school course and the daily occupation of their elders. Parents likewise appreciate the usefulness and the economic value of the special instruction offered. Hence the demand for "Rural" schools has been greater than State finances can satisfy.

'As regards secondary education, the Department is arranging Junior (14 to 16 years of age) and Senior (16 to 18 years of age) Courses of instruction in agricultural subjects. The work for the Junior Classes is largely cultural rather than vocational, but there is sufficient agriculture to stimulate interest in rural problems. The Senior Course is largely agricultural, though more cultural than any similar course in Australian Agricultural Colleges. In the Senior Course the time of the student is equally divided over lecture periods and practical instruction in farming. Instruction is given in all common farming operations, and, in addition, courses in farm carpentry, blacksmithing, engineering, and tractor-driving. The courses given in English are the equal of those necessary to prepare secondary pupils for the University Senior Public Examination. By means of such Junior and Senior Courses it is hoped to make the farmer of the future a well-equipped and skilled worker who suffers not by comparison in culture with what are commonly known as the middle classes. These courses will also furnish the State with a group of young men keenly interested in the application of science to agriculture from whom the official and unofficial leaders of agricultural thought and activity will come.

'These Queensland courses, conducted at the Agricultural High School and College, Gatton, will furnish the new-coming youth from Britain, who have a general education, with a sound knowledge of this State's agricultural methods and the principles underlying scientific agriculture.

'At a later stage it is intended to co-ordinate the activities of the Gatton College with those of the University. When completed, the scheme will be capped by the establishment of a Chair of Agriculture. The completion will satisfy matriculation requirements and thus secure for aspiring agricultural students entrance upon a programme of highly scientific agricultural studies.'

SOUTH AUSTRALIA.

The Superintendent of Secondary Education describes the Agricultural Course adopted in South Australia as follows:—

'The course of study provides that in High Schools where facilities exist the curriculum may be altered with the permission of the Director of Education to include elementary agriculture. The course will extend over two years, and it is intended to develop in the pupils an interest in rural life and to influence those with a natural talent towards agricultural pursuits. It is not intended to provide a course of training that will equip them for farm life, but rather to quicken their interest in agriculture generally, to teach them the main underlying principles of farm operations and to prepare them for further agricultural training at Roseworthy College or

elsewhere. It is further hoped that it will be the means of stemming the tide city-wards and of encouraging boys in country High Schools to seek their life's work in the development of our vast areas. The special feature in any particular school should be determined largely by the nature of the locality and the occupations of the people of the district; for instance, Murray Bridge, which is situated close to a reclaimed area, will specialise in irrigation, dairying, and fruit culture; whereas in a hill district special attention should be given to dairying and gardening, together with the growing of flax, tobacco, and potatoes.

'The curriculum is to be divided into three groups:—

(a) General studies: These will include English, mathematics, history and civics, geography and drawing.

(b) Scientific studies: Chemistry, physics, and botany, in relation to agriculture; agriculture (study of the soil, tillage, water, manures, irrigation, horticulture, planting, training young trees, pruning, budding, grafting, spraying, picking, storing and preserving fruit). Animal knowledge, bird and insect life in their relation to agriculture.

(c) Practical work: Farm mechanics, gardening, irrigation, dairying.'

THE UNION OF SOUTH AFRICA.

In the Annual Report for 1928 the Secretary for Education states:

'The extension of Vocational Education for boys and girls from smaller towns and the countryside should in the immediate future be in the direction of agriculture and housecraft. The Department feels that sufficient attention is not yet being devoted to the special needs of these boys and girls.'

After referring to the difficulties of organising work of this kind in schools the Secretary says:

'I am convinced that the time for establishing more agricultural and housecraft schools has now arrived. The problem of equipping boys and girls by means of education for vocations is one with which all Departments of Education have to deal, and the claim put forward by provincial departments of education that they also are providing education which may be called vocational cannot be denied. Conversely, the Union Department of Education must insist that the vocational education which it supplies has cultural values equal to those which by tradition are regarded as peculiar to the type of education given in provincial schools. It claims that vocational subjects properly taught have a high cultural value, and it strengthens this claim by including in its vocational courses a large amount of so-called cultural subjects.'

Agricultural Science is a subject for Matriculation of the University of South Africa, but is conditional upon the candidates having successfully completed a two-year course in Physical Science at least two years before sitting for the examination. A High School in South Africa offers three standard branches at the top of the system:—viz., 1. Academic (Latin, other languages, Maths., History, Science). 2. Commercial (Languages, Book-keeping, Commercial Mathematics, History and Geography and Science). 3. Agricultural (Languages, Book-keeping, Agricultural Science, Biology, etc.).

The Director of Education summarises the efforts made to bring education into touch with life and nature in Southern Rhodesia as follows:—

1. 'Detailed courses in Nature Study are arranged, the emphasis being laid on practical studies and on direct observation.

2. 'Arrangements are made with the Department of Agriculture by which occasional lectures, sometimes in the classroom, sometimes in the field, and sometimes on the occasion of agricultural shows, are given to school classes by experts of that department.

3. 'There are special competitions in cattle judging provided for school children at agricultural shows, for which prizes are awarded.

4. 'Teachers' vacation courses are annually held in Salisbury, and the subjects studied at such courses invariably include lectures on subjects connected with Agriculture and Public Health. Last year, for example, the courses included lectures on gardening and forestry and on special diseases endemic in this country, *e.g.* malaria and bilharzia, and their causes.

5. 'Agriculture is taught as a subject, especially to pupils of the non-academic type, at two of the seven High Schools in Southern Rhodesia, and experimental plots

are maintained in connexion with these classes. The pupils' work at these plots is a regular part of their school timetable.

6. 'There are special schools of a semi-vocational nature at Bulawayo, where there is a Junior Technical School, and at the Matopos, where there is a Junior School of Agriculture. In both cases, however, about half the pupils' time is taken up with English and ordinary cultural subjects, and the schools in question may therefore be regarded as secondary schools, with, in the one case, a technical, and in the other an agricultural bias. In both cases the schools are at present limited to three-year courses, but it is likely that within the next few years both will be extended so as to occupy the full five years of the secondary school course.'

SECTION IV.

CONCLUSIONS.

In closing their report the Committee wish to state the chief conclusions to which their inquiry has led them, viz :—

(1) That when properly worked the introduction of studies on soil, the growing plant, the management and utilisation of the soil and the broad outlines of agriculture has been found to raise the standard of attainment in other subjects, besides giving boys and girls the kind of practical training necessary to equip them, not only for life overseas, but for life generally.

(2) That examinations for the school certificate should be modified so as to give due credit to practical training.

(3) That there is need for a continued exploration of the whole subject of school curricula with regard (1) to the incorporation of practical subjects, (2) to the development of schemes of practical work suitable for different types of schools—urban as well as country.

(4) That there is even greater need for a thorough exploration of the means for obtaining teachers suitably qualified to undertake the direction of these practical studies.

SECTION V.

The Committee consider that their report would be incomplete without presenting some of the detailed suggestions for syllabuses and schemes of work they have received in the course of their investigation. They have therefore appended these, together with a memorandum on certain aspects of education in rural schools by Sir John Russell.

It is not expected that these schemes can be adopted in the form they are presented; for it cannot be too strongly urged that every school should devise its own scheme; conditions and circumstances vary so widely that it is not possible even if advisable, to set forth a plan applicable to all. It is hoped, however, that the underlying principles will be adopted, and that the various schemes will furnish material adaptable to any school.

1. Memorandum by Sir John Russell, Director of the Rothamsted Experimental Station.

2. Memorandum by Mr. H. W. Cousins, Headmaster of the Grammar School, Ulverston.

3. Scheme of Agricultural Studies at Christ's Hospital, by Mr. G. Green, the master in charge.

4. Memorandum by Mr. G. W. Olive, Headmaster of the Dauntsey School, Wilts.

5. Memorandum by Dr. Vargas Eyre, Director of the Brewers' Research Institute, Epsom; (*late*) Director of the Linen Research Institute, Belfast.

6. Memorandum by Mr. C. H. Lockitt, Headmaster of Grammar School, Bungay.

7. Memorandum by Dr. Neil McQueen, Principal of a Girls' College at Croydon, Sydney, N.S.W.

1. MEMORANDUM ON CERTAIN ASPECTS OF EDUCATION IN RURAL SCHOOLS.

By Sir JOHN RUSSELL.

The chief purpose of the education of a country child is to develop its character and intelligence, to widen its interest, especially in the higher things of life, and to keep alive the inborn curiosity and freshness of outlook that form so much of the charm of youth and afford one of the easiest ways of approaching its best side.

The second purpose is to give the child knowledge that will help it in the constant struggle against Nature, which is the chief activity of the farm worker and the gardener, and enters more or less into the life of everyone who gains his livelihood in the country.

The two purposes are quite distinct, but they are in no wise antagonistic: the same subjects, the same facts and materials, almost the same lessons can serve for both; the distinction is rather in the spirit of the lesson and the perspective than in the matter. The purpose of the teacher should be to give the child the richest, fullest life of which he or she is capable, not to make the child a better labourer. In point of fact, if the main purpose is achieved the second naturally follows.

The Study of the Countryside in Rural Schools.

In these days it is a commonplace to speak of the wonders of science, particularly of such striking achievements as wireless telegraphy, telephony, and transmission of photographs. It is not so widely recognised that science has extended its activities also to the countryside and has produced many useful and remarkable things—such as artificial fertilisers and new varieties of crops. But it has achieved much more than this: it has shown something of the abounding interest and wonder of even the common objects of the countryside. One or two examples only need be given:

A lump of earth is shown to be made up of small particles, each coated with a jelly-like material and possessing certain properties easily demonstrated, even in a village school, that link together much of the fragmentary and disconnected common knowledge of the villagers. The site of the village; the layout of the woods and lanes in the district; the distribution of wood, grass, and arable land; the ease of working the soil; the course of the streams; the position of the bridges and of the stretches of water where paddling is possible. All these and many other things well or partially known in the village follow direct from a knowledge of the constitution of the soil, such as can be imparted to any child above the age of eleven.

Again, the ploughing of farmyard manure into the land is bound up with some of the most interesting modern scientific work in agriculture. Farmyard manure is not itself a plant-food; it is indeed harmful to plants. In the soil, however, it undergoes a remarkable change; it is converted into a highly effective plant-food. Science has shown that this change is brought about by a multitude of micro-organisms which live in the soil, invisible to the naked eye but easily demonstrated by simple experiments. The organisms are present in all soils and in dirt; they are very effective transformers, changing sweet milk to sour, making meat putrid, causing wounds to fester, and generally producing those changes associated with dirt in the larder, the dairy, or the home.

Instances might be multiplied to show that the facts and phenomena forming the background of village knowledge and experience are the effects of agencies or of forces which can, in broad outline, be demonstrated to the child, and which, if adequately presented, make up a story of absorbing interest and of the utmost value for keeping alive and developing the native curiosity of the child, for training its powers of observation and stimulating it to think about what it has seen.

It has always appeared to me somewhat pathetic that the child who will, presumably, spend his or her life in the country and probably work upon a farm should know so little of the interest and wonder of the things around him. I know from actual experience in a country school how lively an interest can be aroused in the children. When living at Wye, I used to give one lesson a week to the assembled 4th, 5th, 6th, and 7th Standard boys and girls, and found them eager, alert, and quick to grasp the points.

The English countryside as we see it to-day is the resultant of the activity of the human and natural forces, and it cannot be properly understood unless the human

activities are also known. The Celts, Romans, Saxons, Normans, and English who in living procession have trodden the roads of England have left traces in almost every shire, and in many parishes and villages. The lanes, the names of the fields and farms, the church, and the old houses in the village all tell something of bygone days, and can be brought in to help the child to reconstruct the pageant of the village history.

AN OUTLINE OF A COURSE.

The Countryside : the natural basis.

In the book 'Lessons on Soil,' by Sir John Russell, is set out the substance of the lessons he gave to the village children at Wye, put, however, into rather more general form so as to make the material more useful to teachers. Beginning with known facts and observations collected by the children, and making a few simple and obvious tests, elicited in the main from the class, it was found possible to build up a coherent account of the surrounding district which stimulated their curiosity, made them observe and inquire, and gave the teacher many opportunities of showing something of the wonder and mystery of the things around them. And, although there had been no vocational purpose, the lessons gave the children a working knowledge of the properties of soils, plant-growth, and cultivation processes that could not—and did not—fail to help them subsequently in their daily work on a farm or in a garden.

The Countryside : the human factor.

Simultaneously the child should be taught something of the history of the countryside so that he may know and understand what manner of men and women it was who cleared the site, built the village, laid out the farms, and developed the agricultural system now in use; how people lived in the old days, and what is the meaning of the traces still left in the villages by the former generations. This would naturally be part and parcel of the full history course; the child must see his village as a part of the whole; there should be no water-tight divisions between general and village or agricultural history. Properly arranged, a course like this should prove very effective in stimulating the imagination, widening the outlook, and developing a sense of pride in the village, the county, and the country.

Man's control : the story of the farm.

This part consists in the application of the material gathered in the first and second parts to the more detailed study of the farming of the district: the stages in the transition from the old complete self-supply system to the modern specialised production; the reasons for the change and why the present system was adopted. The economic factor must here be introduced. The difficulties and pitfalls are obvious, but one must trust the teacher to treat the subject dispassionately and without party bias; the basis of the treatment should be historical. The technical side must also be developed, and this can be merged to any desired extent into definite farm or garden teaching and handicraft. With this can be associated the formation among the scholars of such groups as Young Farmers' Clubs, Pig Clubs, Poultry Clubs, etc.

For the technical side the treatment should be both historical and scientific: English agricultural methods are deeply rooted in the past and can be fully appreciated only when their origins are known. But they have been shaped to their present form by the interplay of economic and natural forces, and the latter can be discussed with a class that has studied Part I of the course.

The equipment necessary.

For the first part the equipment needed is relatively simple. The soil section is sufficiently discussed in 'Lessons on Soil.' A parallel course on plants could be set up without difficulty; the school garden forms the basis of the work: search among existing books would almost certainly discover some suitable for the scholars' guidance. A survey of the district forms an integral part of the course—for this the Geographical Association is able to render assistance through its local branches. A number of the rural school teachers by means of summer courses have already given themselves much of the necessary training. These courses serve the valuable

purpose of enabling teachers to correct their perspective and to obtain detailed information on matters of local importance about which the ordinary reference books have little to say. It is imperative that the study should be systematic and continuous; if the lessons are unconnected the child misses the essential fact of the far-reaching effects of simple properties and natural laws: incidentally it also loses much of the value of the mental training.

For the second part county histories, geography, and literature fall easily and naturally as well as for the next part of the course.

For the third part the best book would be a simplified and shortened version of Lord Emile's 'English Farming: Past and Present,' combined with a general account of the main movements of history.

The technical side no longer presents the difficulties it did before the War. A number of County Agricultural Institutes have been set up, with staffs trained to give appropriate instruction. It is desirable to effect co-operation with these bodies. It is not desirable to set up anything in the nature of a farm corresponding to the school garden: the difficulties are too great and would overburden the teacher. The County Institute has already the organisation, and it is the goal for which the best of the scholars who intend to stay on the land should be aiming. The sooner, therefore, they come under its influence the better.

Into the details of the Technical Course it is impossible to enter. No rigid course can be prescribed, but much must depend on the local type of agriculture and the local facilities. If co-operation with the County Agricultural Institute can be effected the details for the courses of instruction should be worked out in collaboration with the staff.

2. MEMORANDUM ON RURAL BIAS IN A COUNTY SECONDARY SCHOOL.

By H. W. COUSINS.¹

The Brampton County Secondary School, maintained by the Cumberland County Council, draws its pupils mainly from an agricultural district of a population of approximately 8,800.

It is a mixed school of 60 boys and 60 girls, established in 1908, with a curriculum of a definitely rural bias. Practical experiments on the land have been carried out largely by boys in the extensive grounds of the school ever since its foundation, and the results have been made use of to illustrate laboratory work in science. In view of the smallness of the school the problem became that of devising a single course in science which should provide for the intending farmer a sure grounding in the sciences underlying modern farm practice, but which would not penalise the boy intending to study pure or applied (other than agriculture) science at a University, or to enter any of the usual trades or professions.

The principal difficulty has been that of reconciling the work of the school with the matriculation requirements of the various Universities. The ground was cleared by the Durham University School Examination Committee, who, to meet the needs of the school, added to the syllabus of examination a special science syllabus termed 'Experimental Science in relation to Agricultural Life.' The University further agreed to accept a success in this subject at the 'credit' standard for matriculation. Later, other Universities followed this course.

The syllabus added below was introduced in 1918, and shows the nature of the work up to the stage of the School Certificate Examination. The tables given illustrate the character of the experiments carried out in the school gardens.

It is important to note that the syllabus is in no sense to be regarded as final. New methods of approach and fresh sources of lesson material are constantly being sought and tested. Thus, at the present time, since butter-making has been added to the curriculum for the girls, experiments are being made to find how far the course can go in the study of bacteria, etc.

It is unfortunate that few boys intending to take up farming remain at school after the age of 16, and consequently post-matriculation developments of the course have not been possible. It is hoped, however, that in this direction there may be improvement in the future.

¹ Mr. Cousins left Brampton in 1928. This memorandum was in 1925.

Concerning the general work of the school, it only remains to say that it follows that of any other secondary school earning grants from the Board of Education. Religious knowledge, English language and literature, modern history, geography, French, mathematics, music, drawing, housecraft (for girls) and manual instruction (for boys) all occupy the usual place in the curriculum. Latin is taught where necessary, but to selected pupils only.

It is important to emphasise at the outset that the *raison d'être* governing all the experiments at this school has been the wish to give children the best possible training—in every sense of the word—in a mixed school drawing its pupils from a district almost purely agricultural, and compelled on the one hand to prepare some pupils for the usual Lower and Higher School Certificates as a passport to the Universities and the professions, and on the other for life on the land or for entry to some trade or branch of business life. It has never been the purpose of the Governors or staff to give definite agricultural teaching as a preparation for farming, to the exclusion of the interests of the majority of the pupils. Such a policy would have been fatal to the school, and no less injurious to the best interests of the future farmer; and that for two main reasons—the district is not sufficiently populous to maintain a school with a purely 'farming' type of curriculum, while the segregation on vocational grounds of children of secondary school age is most undesirable.

It is impossible in a short report to discuss the pros and cons of such a wide and deep subject as the curriculum of a school, or even to make a plain statement of the complete problem as it presents itself to one's mind. At the risk of being misunderstood, the writer must therefore content himself with a very brief statement of the essentials of a good curriculum as they appear to him.

1. It should have a real relation to the child's life—past, present, and future—otherwise it is almost impossible to secure the pupil's interest and co-operation, without which good work is impossible.

2. It should be broad enough to appeal to the many sides of the individual child and to the varied tastes and inclinations found in an average form. To this end practical work—such as woodwork, metalwork, domestic subjects, dairying, etc.—and 'outdoor' work in geography, mathematics, science, history, etc., must receive proper recognition and an adequate allotment of time.

3. It should be sufficiently elastic in content and method to extend the keen and able student without unduly depressing the *supposed* dull and backward.

4. It must give reasonable opportunities for training children to appreciate art, music, etc.

5. It must, above all, secure that a child leaves school with the wish to learn by practice and through precept, and that he knows, when left to his own devices, how to learn.

Believing in these principles, the writer has continually urged members of his staff to base their teaching as far as possible on the lessons afforded and suggested by the school environment, and to endeavour to give full play to the individual leanings of the children.

That does not mean the outlook is to be parochial, but that the local interest serves, not necessarily as a focus, but certainly to help to focus the world as a whole and to bring the individual into right relations with the community. The study, too, of the individual child, and the attempt to make the curriculum fit him, instead of trying to fit him to the curriculum, gives every child the chance of proving that he is good at something. This is most important. The traditional type of academic curriculum so often only serves to suggest to a boy that in comparison with his fellows he is a dunce. Surely there is something wrong with a system that allows this! And is it not true that the pupils who are thorns in the flesh of the form master often prove in after life to be the very 'salt of the earth'? Among the men who have built our Empire—the pioneers, administrators, business men, etc.—men gifted with insight, initiative, organising capacity, etc., there are hundreds and thousands to whom the book and pen made little appeal.

If the school is to do its work thoroughly, it must recognise that the word ability has a much wider meaning than is often granted to it; and must make provision for the practical type of boy no less than for the fellow who is destined to shine in 'book' work.

The writer claims that for a country school a curriculum with a marked rural

and, in a limited sense, agricultural, bias, and which gives generous opportunities for so-called practical work in many directions, provides a much better training for life for the average child than an education that is almost wholly bookish.

There are, of course, drawbacks to such practice. The requirements of the Lower School Certificate Examination present some difficulties, but examining bodies now look much more sympathetically than of yore on the claims of teachers to determine what they shall teach. After the Lower Certificate stage difficulty in this direction vanishes. Indeed, it would appear from the evidence the writer has—an amount too small, however, for any sweeping generalisation—that far better work, both in quantity and quality, is obtained at this stage when pupils have worked for some years previously through a course with a marked rural bias. This is no doubt largely because rural work—in science especially—affords a unique training in patient and persistent observation and experiment over long periods of time, and discourages entirely the spasmodic and bitty work that is not infrequently characteristic of pupils with high ability. Again, as probably the majority of teachers will agree, success in academic work of Higher Certificate standard or in the work of any business or profession, depends in the main on the individual's capacity and desire to map out and master his tasks without constant help from teacher or employer. It is comparatively easy to spoon-feed the average pupil through the Lower Certificate stage, but almost impossible to carry him much farther by such means.

Now the intensity of interest that is secured when 'local' colouring is constantly given to lessons, when there are opportunities for clever practical children to illustrate geography, history, and science lessons by models, apparatus, etc., made in the workshop, and when there is proper correlation between the various subjects of the curriculum, affords a training in initiative and self-reliance that is of the greatest value in the later years of the child's school career. In the early years of training method is everything. The content of the curriculum is then not nearly so important.

The whole matter, however, is too big to argue out in a short paper, but it is beyond question—in the writer's opinion—that pupils intending to take higher certificate and scholarship examinations are not at all handicapped in Science or Arts because they have worked on the lines indicated up to the Lower Certificate.

Experienced teachers will have little difficulty in appreciating the extent and directions in which mathematics, geography, and craftwork can be made more vivid and living by the application of rural bias. The economic life of the countryside—the weekly transactions in the local market; the periodical sales of cattle and sheep; the trade of cake, seed, wool, and corn merchants; the letting of 'accommodation' land; the effect of weather on prices, etc.—has a great attraction for the average country child. He often, too, displays an amazingly full knowledge of details of which the wise teacher will not fail to make full use as starting-points in many lessons.

History, again, is a subject made all the stronger in its appeal to the country child if taught with a strong rural bias.

Thus, in dealing with the Tudor Period and tracing out the causes which, through the increased importance of sheep-rearing and a reduction in the amount of arable land, led to distress and unemployment among agricultural workers and to the Poor Laws of Elizabeth and of later years, one passes naturally and convincingly to a comparison with present-day conditions when cheap grain from abroad increases the area under grass at home, and displaces labour from the farms.

And, as with all the subjects mentioned specifically above, there is no subject of the curriculum that does not lend itself naturally and profitably to 'rural colouring.'

From the point of view of the pupil intended for life on the land, or for some occupation, such as accountancy, banking, business, that must bring him into daily contact with farmers and other land workers, a curriculum on the lines favoured above must prove directly helpful both in increasing his love for, and sympathy with, rural life, and in making him technically more efficient. Yet it is of the utmost importance to remember that much evidence is accumulating in this and other countries to prove that the same curriculum affords also the best possible training for any child living in the country, no matter where or what his future work may be.

It only remains to give some particulars of the practical work attempted in connexion with the science course.

Over two acres of land are under cultivation, and much of the actual manual

work is done by a gardener and a general labourer, whose wages are paid by the local education authority. The whole cost of labour does not fall on the authority, however, for the gardens supply all the potatoes and other vegetables used in preparing the school dinner—about eighty to ninety staff and pupils dine at school each day.

In the junior forms only the boys actually work in the garden, but both boys and girls make full use of the grounds and greenhouse as an open-air laboratory. In the senior forms boys and girls are on an equal footing, and make the fullest possible use of both garden and greenhouse, assisting in various cultural operations when necessary, and carrying out regular and systematic work in plant physiology, control of pests, soil physics, etc., in pots and on the land. The time allotted to actual outdoor work at any stage of the course is not specified. Indeed, to do so would be altogether fatal to the meaning and value of the work. The object of the course is to train children in habits of scientific method and to make them useful citizens. It is not the aim of the school to teach the children to raise big crops of potatoes. If the course, however, does help them to grow bumper crops, so much the better.

In concluding this very brief account of a curriculum that has proved eminently practicable, it is hoped that fellow-teachers will be kindly in their criticisms.

The work is still in the experimental stage, and many factors exist which make both additions and eliminations difficult.

But even as it stands it is claimed that educationally it is sound, and that, up to the age of 16 or thereabouts, it meets the needs of every child, whether he be destined to enter a university or to follow the plough.

Distribution of Time.

The figures given below show the number of lesson periods per week allotted to each subject. Lesson periods are 40 to 45 minutes. Forms Va and Vb take the Lower Certificate:—

	Va & Vb. B. G.	Vc. B. G.	IV. B. G.	IIIa. B. G.	IIIb. B. G.	II. B. G.
Scripture.	1 1	1 1	1 1	1 1	1 1	1 1
English	5 5	4 4	4 4	4 4	4 4	5 5
History	3 3	2 2	2 2	2 2	2 2	2 2
Geography	3 3	2 2	2 2	2 2	2 2	2 2
French	5 5	4 4	4 4	4 4	4 4	3 3
Mathematics	6 6	6 6	6 6	6 6	6 6	6 6
Science, including Out- door Work	4 4	6 6	6 6	6 4	6 4	4 2
Manual Work	— —	3 —	3 —	3 —	3 —	5 3
Domestic Science	— —	— 3	— 3	{ — 3	— 3	— 2
Needlework	— 2 }			{ — 2	— 2	— 2
Drill and Folk Dancing	1 1	1 1	1 1	1 1	1 1	1 1
Preparation	3 1	2 2	2 2	2 2	2 2	2 2
Music	1 1	1 1	1 1	1 1	1 1	1 1
Games	1 1	1 1	1 1	1 1	1 1	1 1
Art.	2 2	2 2	2 2	2 2	2 2	2 2
Total	35 35	35 35	35 35	35 35	35 35	35 35

Special pupils taking Latin may be allowed to omit Drawing or Manual Work or Domestic Science by arrangement with H.M.I., otherwise the subject is taken after the usual school hours.

Pupils in Form VI.—i.e. post-Matriculation—work to individual time-tables according to their requirements.

Domestic Science for Vc girls includes instruction in butter-making and soft cheese-making. This work is linked up with the Science Course.

Science Syllabus.

The syllabus is based on three main conceptions as to the function of a science course :—

(1) A fundamental course in the major sciences—physics and chemistry—because of their influence—

- (a) on other sciences ;
- (b) on the teaching of scientific method ;
- (c) on the higher work which some pupils will undertake.

(2) The need for stimulus of contact with objects outside the laboratory, hence the biological, and in a narrower sense agricultural, bias ; these supply the means whereby the knowledge and method taught indoors might be applied. The grounds and gardens of the school are therefore treated as an outdoor laboratory in which a variety of interesting experiments may be carried out.

(3) Throughout the course individual experimental work is demanded, wherever feasible, in the hope that this will strengthen initiative, self-reliance, etc., in the pupil.

Form II.—Boys and Girls. Average age 11.

A. An Introduction to Gardening. Hours per week, $1\frac{1}{2}$.

Simple seasonal activities, *e.g.* : (a) seed-sowing—transplanting seedlings ;

(b) cuttings—various ; (c) planting bulbs ; (d) saving of seed.

Care of small area of ground for : (e) raising plants from seed—annuals, etc. ;

(f) wild garden—weeds.

Form II.—Boys only.

B. Gardening (working in pairs on plots of 100 sq. yds.). Hours per week, $1\frac{1}{2}$.

Rotation : (a) potatoes ; (b) beet and carrot ; (c) cabbage, garden swede ; (d) green manure.

Use and care of tools—digging, trenching, etc. Manuring—preparation of seed-beds—sowing, thinning, etc.—lifting and storing of various crops.

Preparation of seed order—planning of plots—weighing and costing produce.

Pests and diseases—life histories of some of them.

Preparation of labels for plots.

(Board of Agriculture Leaflets for work indoors in bad weather.)

Form IIIb.—Boys and Girls. Average age 12. Hours per week, 3.

A. and B. Introduction to Botany.

A series of drawings are prepared (loose sheets in portfolio) : (a) twigs from trees in school grounds ; (b) bulbs, etc.—crocus, montbretia, hyacinth ; (c) flowers—those presenting simple structure, so as to lead up to : (1) a complete flower ; (2) floral diagrams ; (3) floral formulæ ; (4) similarity of arrangement.

(Part of the work is done in the drawing classes.)

Boys only. Hours per week, $1\frac{1}{2}$.

C. Gardening : as for Form II., but with greater variety of crops.

(*N.B.*—New pupils starting in this form with no knowledge of gardening are usually placed with more experienced pupils.)

Form IIIa.—Boys and Girls. Average age 13. Hours per week, 3.

A. Physics.

Experimental work dealing with : (a) measurement of length, area, volume etc. ; (b) the balance—weighing ; (c) density and relative density ; (d) Archimedes' Law—fluid pressure ; (e) the barometer.

B. Botany.

The work started in Form IIIb. is continued with a view to starting a Flora in Form IV.

Boys only.

D. Gardening.

The boys work a 'common plot' with the following rotation :

(1) potatoes ; (2) beet and carrots ; (3) onions ; (4) cabbage family.

Experimental work on common plot : (a) variety trials ; (b) seed-saving—selection of type ; (c) control of pests and diseases—spraying ; (d) raising of seed potatoes—rogueing ; (e) influence of spacing of crops ; (f) simple manurial experiments.

In addition each boy prunes, feeds, and generally manages :

(1) an apple-tree ; (2) a soft-fruit bush—gooseberry or red currant.

C. Other activities.

- (1) The class records observations made of air temperature and soil temperature ;
- (2) Raises when necessary supplies of plants having special botanical significance.

Form IV.—Boys and Girls. Average age, 14. Hours per week, $4\frac{1}{2}$.

A. Chemistry.

- (a) Experimental study of the following: The atmosphere, water, oxygen, hydrogen, nitrogen, oxides, acids, bases and salts, carbon dioxide, ammonia, common calcium compounds; (b) in addition the following: law of constant composition, chemical change, chemical equations, symbols, formulæ, atoms and molecules.

B. and C. Plant life, etc.

- (a) Seeds and seedlings, individual experimental work—*e.g.*: structure of seed; absorption of water by seed; increase in weight and volume; respiration of seed, effect of temperature on germination; (b) plant nutrition; water cultures, sand cultures. Potato experiments (eight-plot test: law of diminishing returns; observation of same only; results considered in Vc); photosynthesis, respiration in plants and animals; (c) the use of a Flora; (d) work in the garden: (i.) raising plants from seed, etc.; (ii.) management of border; (iii.) experiments arising from the indoor course.

Form Vc.—Boys and Girls. Average age, 15. Hours per week, $4\frac{1}{2}$.

A. Chemistry continued:

- (a) The three mineral acids—preparation, composition and reactions, sodium, potassium—their hydroxides: phosphorus, sulphur, and carbon—their oxides and acids derived from same: phosphates, sulphates, carbonates; salts of importance in agriculture; (b) organic chemistry—introduction to such materials as proteins, fats, and carbohydrates, by examination of simple foodstuffs and vegetable matter.

B. Physics.

Simple treatment of energy—transformation and conservation of energy—electricity, light, heat, etc., as forms of energy. Heat treated in greater detail: the thermometer—time temperature curves. Change of state—latent heat; boiling points, etc.; quantity of heat—specific heat. Expansion, conduction, convection, radiation.

C. and D. Plant life, etc.

- (1) Soil—origin—structure—water content—organic content—clay, sand, and humus—pore space, air space. Movement of water in soil—capillarity—surface tension—diffusion—effect of cultural operations on water content. Soil temperature—factors controlling it, drainage—hedges—slope—colour. Micro-organisms present in soil—fermentation, decay—nitrification; denitrification—bacteria in relation to food—milk, butter. (2) Experimental results—consideration of numerical results from various experiments (chiefly dealing with potatoes). (3) Greenhouse and frames. In relation to radiation, convection, sunshine, humidity of atmosphere, etc.

Form Va. and b. Average age, 16. Hours per week, 3.

The whole of the previous year's work revised, with necessary extension and amplification, *e.g.* the vernier, Boyle's Law, fluid pressure, comparison of plant ash with soil, physical and chemical processes involved in composition and decomposition of plants and animals. Other elements of importance in plant nutrition, *e.g.* magnesium, iron—their oxides and common salts.

Potato Experiments, 1925: Law of Diminishing Returns.

Nine plots are used on which potatoes are grown with variable quantities of potash and nitrogen (phosphates constant).

The data are used for such problems as—

1. Calculation of weight of fertiliser to be applied.
2. Calculation of percentage of potash, phosphates, and nitrates in dressing.
3. Calculations of yield: total crop per acre and ratio of crop to seed.
4. Comparison of yields.
5. Relation between yield, cost, etc.

In addition, useful observations are made by the children during the growing season.

Variety trials.—A number of varieties is grown in sextuplicate on a plot 55 ft. by 205 ft.—six sections.

One section is trenched each year—the others are worked one spit deep. At the same time the trenched section has garden refuse worked into the second spit. All sections are dressed with artificial fertilisers in spring. No dung is available, but rape meal has been used during the last year. The yields are calculated on tons per acre and also crop : seed. Since 1919 we have grown more than twenty immune varieties.

Varieties for 1925.—Tinwald Perfection, Kerr's Pink, Catriona, Katie Glover, Ally, Arran Comrade, Kok.

Varieties on small plots.—Field-Marshal, Majestic, Di Vernon, Arran Chief, King Edward, Ben Lomond, Golden Wonder, Crusader, Ben Cruachan, Immune Ashleaf.

Seed size trial.—This year we are planting sets of Arran Comrade and Tinwald Perfection from tops of known yield. Strong tops and weak tops were selected last year from a plot of the above varieties planted very widely (rows 4 ft., sets 3 ft.), so as to remove any possibility of mutual interference.

The tubers, ranging from 1 oz. to 3 oz., have been selected and planted this year in the same way as the previous generation (common plot).

Cut set trial.—Tubers were cut so as to have a good sprout on each portion. One group of such portions was exposed to the sun and wind before planting. Another was kept under a damp sack for a similar period of time (dual plots).

On the same plots it is proposed to try planting potato sprouts with a very small portion of tuber attached (after suitable period under sack to allow the cut surfaces to seal themselves).

3. SCHEME OF AGRICULTURAL STUDIES AT CHRIST'S HOSPITAL.

The Agricultural work at Christ's Hospital has been an experiment applied mainly to the occupation and development of boys who show little progress under ordinary school curriculum.

When a boy in the Middle School has remained there long enough to have studied the chemistry of air and water, etc., he usually gets the opportunity of joining a class for elementary biology in connexion with practical work on a small experimental farm of five acres. He is kept in this set for a year if possible, but it often happens he passes on to the form above at the end of one or two terms only. He may then, if he wishes, join the agricultural class proper, with the intention of going on the land when he leaves the school. This class consists of about 16 boys. Their time-table enables them to spend two whole mornings per week on agricultural studies, including practical work on the land, tending and feeding a horse, pigs, goats, poultry, and bees; or biological work in the laboratory, or out of doors; the rest of their time is devoted to Chemistry, Mathematics, History, Geography, and Manual instruction.

The Agricultural Scheme consists of the following :—

(a) to run a 5-acre strip of land as a miniature farm for crops and stock (including pigs, fowls, goats, rabbits, and bees), to which has been added lately 2 acres of grass land;

(b) to study rotation of crops and permanent wheat strip with various manured sections. These give enough elementary knowledge of results of chemical manures, etc. to lead to a desire for more;

(c) to use the grass land in part for manure tests on permanent grass lands;

(d) to give boys a turn at being stockmen, carters, accountants, record keepers, naturalists (collectors of insect pests, and weeds, etc.);

(e) to encourage boys to look upon the farm as their own, and to hold them responsible for its condition. They are under orders themselves to find something to do which they see requires doing when no definite job is allotted to them. This leads to much discussion why they decide a certain thing is more urgent than another.

The Science Master in charge says in reference to the work :

'I have found that there is always something new one can use as educational material, and I change my material pretty frequently to suit the nature of the boys, the varying seasons, and other conditions. This is one of the most valuable features of the subject for schools in my opinion. It prevents staleness and getting into a rut both for teacher and taught, but it requires a wide knowledge, and much experience of boys.

'My agricultural form is in most ways quite a joy to me. I see boys who could be made nothing of by other means becoming useful citizens, and even developing intelligence of a kind, and self-reliance, and that in spite of the fact that they are in some cases boys who have not only been rejected as poor brains, but as doubtful characters also. My present class consists of boys, some of whom have been with me four terms, some three terms, some two, and some only one term. This is usual and cannot be helped. It becomes essential, however, not to keep to the same branches of the subject each year, otherwise the older members spoil the freshness of it for the younger ones.

'The following indicates a line of interest that emerged spontaneously :—

'A JAM FACTORY.

'Last term we had a lot of marrows, and some of the boys suggested we should make jam. I saw possibilities in this, so we used our portable boiler, and made quite a profitable thing out of it. Here was a rural industry which brought in quite a lot of new material for study. Some jam was left uncovered, fermentation set in, bacteria, moulds of different kinds led to a natural desire to know more about these organisms, this led to bean roots, and so by a new approach to a cycle of changes.

'AGRICULTURAL RETURNS.

'On another day Agricultural Returns from the Ministry of Agriculture arrived—it happened to be a wet day. We studied them and made graphs—this led to a natural desire to know how the yield of our own plots compared with the averages given in the returns. Record books were consulted, calculations made eagerly (because not forced) as to yield per acre for unmanured and differently manured plots for some crops; money value of crops and manures were compared, profit and loss discovered.

'Afterwards one boy, reputed dull when he joined the class, asked if he could take the record books to his house and work out the results of the other crops in the same way.

'One cannot make out a syllabus for this kind of work. I did not know it was going to lead so far when I opened the envelope of the Ministry of Agriculture that morning.'

4. MEMORANDUM FROM MR. G. W. OLIVE, HEADMASTER OF DAUNTSEY SCHOOL, WILTSHIRE.

The essential basis of a course is a good education, including a fundamental knowledge of General Science, and in the absence of the latter, an elementary course of Air, Water, Soil, and Life, at least must first be given.

The course should be experimental. Its value should in no wise be regarded as merely a vocational or commercial one. The spirit that inspires and operates should be educational.

Throughout the course the story of progress and human effort should be introduced, and the qualities of accuracy and manipulative skill should be engendered.

The selection of the studies and the details of the *syllabuses of the studies must be determined by each school according to its own special facilities, e.g.*: The question of including or excluding, say, Economics, Book-keeping, Dairying, Bee-keeping, or Woodwork, should be left to those actually responsible for the organisation of the work in the school. It is felt, however, that Chemistry, Physics, Biology, Geology, History, Mathematics, and Handwork are essential. On the other hand, for example, the amount of attention and time given to actual farm work, to the consideration of Crop Production, to the study of Bacteria, to Book-keeping, and the manner in which they are treated, are matters which must be left with and decided by each school independently.

The conduction of the course must usually be a *matter of understanding and agreement and treatment by the various members of the staff*. Clearly each school must try out a course of its own adapted to the facilities and the environments, the teaching staff, and similar factors, and therefore freedom rather than definite syllabuses are regarded as being essential to the success of the course.

I. THE CHALK PLAIN OF SALISBURY.

A project of multiple interests linking up different subjects of study.

Forces of nature and man are reflected in every part of Salisbury Plain. The fact that Salisbury Plain is of a chalk formation has influenced the resultant of these forces to a very large degree.

The study of the essential properties of the Chalk Plain—through the medium of geology and soil study—will explain how the chalk formation has influenced History and Literature, Economics, Agriculture and other features of the Plain.

Geology of Salisbury Plain.

Some special features emphasised in class and field work :—

1. Chalk—three divisions :

Upper, chalk with many flints.

Middle, chalk with few flints (pervious).

Lower, chalk marl, *i.e.* chalk and clay (impervious).

2. Scenic features—chalk escarpment caused by change from Middle to Lower chalk :

Springs at the junction (Upper, Middle, Lower).

Characteristic rolling surface—dry valleys—thin soil, because chalk almost all calcium carbonate, therefore few trees and fine grasses, and characteristic chalk-loving plants and animal life.

Where Upper chalk is covered by a deeper soil (remains of tertiary deposits) heavier vegetation, including beech trees, characteristic. (William Cobbett's 'Rural Rides' bring these and other points into prominence in a most interesting fashion.)

3. Origin of chalk from marine deposits.

4. Presence of flints—their connexion with the Stone Age and their value in the draining properties of the soil.

5. Origin of springs and their relation to position of farmsteads, and position of hamlets, etc.

Chemistry and Physics, and Biology of the Chalk Soil, and of Chalk.

Some features emphasised in class and field work :—

1. Elementary properties of chalk soil (chemical, physical, and biological).

This provides excellent material for work in laboratory and in the field, and at the same time demonstrates very clearly the principles underlying the system of farming as practised on the Plain.

2. Pure chemistry of calcium carbonate, oxide, hydroxide, and bi-carbonate leads to hardness of water, difficulty of maintaining water cultures of certain protozoa, and other micro-organisms where alkalinity is harmful, etc.

The study involved under (1) Geology, (2) Chemistry, Physics, and Biology of chalk soil has an important bearing on the History, and Literature, Agriculture, Economics, and Natural History, because the study brings at least two fundamental facts, *viz.* :—

(a) The Plain has long been suitable for human habitations.

(b) The soil is fertile when well cultivated.

In order to illustrate the connexion a portion of the outline of each syllabus is given in the case of History and Agriculture.

History.

Stone Age, Bronze Age, Iron Age—Celts and Romans, British on the Plain.

Avebury, Stonehenge, Woodhenge, Battlebury, Scratchbury, Bratton, etc.

Romans at strategic points, Saxons along the river banks.

Succession of peoples at Old Sarum—Danes at Edington (Bratton).

Normans at Old Sarum, Devizes, etc.

Sheep and corn gave prosperity, therefore churches and rise of towns, *e.g.* Trowbridge.

History of powerful families and of buildings—place names, etc.

Literature : 'Rural Rides,' William Cobbett (Everyman's Series—most illuminating) ; 'The Georgics,' Pepys, 'Coaching Days,' and many local histories.

Agriculture.

Sheep and corn are the foundation of agriculture of Salisbury Plain.

Sheep and corn and prosperity all interdependent, sheep give manure and lift of water.

Typical rotation : Double four-course rotation :—

1. Two root crops for sheep, as a preparation for two corn crops.

2. Two grass crops for sheep and two corn crops.

Roots, straw, hay, made possible 'folding' of early maturity Hampshire Down Sheep. History of Hampshire Down Sheep.

Sheep runs ; West of England cloth mills. Dew Ponds, Lynchets.

Celtic and Saxon type of farming. (During the Great War 200 acres of wheat were common.) Big field methods and general prosperity are reflected in the farm buildings, machinery, and implements, *e.g.* pressers, hay sweeps, tractors.

Natural History : No outline of the work done is given, but this shows clearly the connexion between the life on the Plain and the nature of the Plain itself.

Mathematics, Surveying, and Booking are naturally introduced into the scheme.

II. INTERCONVERTIBILITY OF ENERGY.

Experiments performed by boys in Middle School in 1926 Summer Term as part of an Educational Experiment.

The following experiments were performed in 1926 (Summer Term) by a group of boys in order to illustrate the principle of Interconvertibility of Energy. The pages were taken from the Annual Report (which deals with the aims and methods used in the school).

A series of experiments and charts is shown to illustrate the fact that the various forms of energy are mutually convertible. The subject is chosen in order to show that all branches of science are involved when dealing with a fundamental law such as the Conservation of Energy. This serves as an antithesis to 'Iron in the History of Mankind,' where one substance is seen to permeate all science, history, and geography.

It may be found that certain experiments, although not in the same setting, seem to occur each year. This brings out the fact that such experiments are illustrative of more than one scientific law or phenomenon.

Changes are shown between the following forms of energy, Mechanical, Chemical, Electric, Heat, and Light. The experiments are arranged as far as possible in the order of the adjoining chart.

A demonstration of the telephone and the transmission and reception of wireless telegraphy shows how a number of energy transformations are embodied in everyday applications of science. Other important points dealing with the subject of energy are dealt with in the following charts :—

- (1) Natural sources of energy.
- (2) The sun as the original source of all forms of energy.
- (3) The work of Count Rumford and James Joule.
- (4) The gamut of Ether Waves.

Changes of Mechanical Energy.

<p>Into.</p> <p>Chemical.</p> <p>Sodium Amalgam, and Mercuric iodide are taken as examples.</p> <p>Electrical.</p> <p>Static Electricity is produced by the rubbing of a vulcanite rod and its effect is shown on a spray of water.</p> <p>Current Electricity was first produced from mechanical action in Faraday's classical experiment on Electro-Magnetic Induction. This now forms the basis of the Dynamo.</p>	<p>From.</p> <p>Chemical.</p> <p>The Ammonia Fountain.</p> <p>The Petrol Engine, at the Workshops.</p> <p>Electrical.</p> <p>The reverse effect is shown on a silk tassel.</p> <p>The mechanical effect of an electric current was discovered accidentally by Oersted. This effect is the principle of the Galvanometer and Electric Motor.</p>
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Changes of Mechanical Energy—cont.

Into.	From.
<p>Heat. The degradation of mechanical energy into heat is commonly said to be due to friction. An illustrative example is shown at the Workshops.</p>	<p>Heat. The slow change is illustrated by the force due to the contraction of iron bar. The more violent change is to be seen in all Steam Engines. In each case the force comes from the alteration in volume of substances when their temperature is changed.</p>
<p>Light. The production of sparks from steel and flint has been known since the earliest times.</p>	<p>Light. In Crookes' Radiometer, the vanes rotate owing to the differential effect of light on the polished and dull surfaces respectively.</p>

Changes of Chemical Energy.

Into.	From.
<p>Electrical. Zinc and Copper in sulphuric acid produce an electric current when joined by a wire, but heat when there is no circuit.</p>	<p>Electrical. Electrolysis of Copper Sulphate solution and water shows the reverse change.</p>
<p>Heat. Among numerous instances of this change is the result of mixing water and concentrated sulphuric acid. The Thermite process.</p>	<p>Heat. The ignition of phosphorus; the heat required for the ignition being actually generated as the phosphorus combines with oxygen.</p>
<p>Light. Many chemical actions produce light as flashes. The action of Chlorine on Acetylene is chosen as an example.</p>	<p>Light. The action of light in producing a chemical reaction is shown best in photography; parts of the chemistry of photography are demonstrated.</p>

Changes of Electrical Energy.

Into.	From.
<p>Heat. The use of fuse wire embodies this change.</p>	<p>Heat. The reverse effect is brought about by the Thermopile.</p>
<p>Light. Actinic light such as X-rays is given by a high potential current passing through an evacuated glass bulb.</p>	

Energy Changes among Living Organisms;

Into.	From.
<p>Potential Energy in Organic molecules of Green Plants.</p>	<p>Sun's Light—(Kinetic Energy).</p>
<p>Potential Energy.</p>	<p>Kinetic—Plant Activity. Energy—Animal Movement. Animal Heat.</p>

Experiments performed by another group of boys, related to :—
 Assimilation, Respiration, Stimuli, Animal Heat, Movement, etc.

III. EXPERIMENTS PERFORMED BY THE LOWEST FORM OF THE SCHOOL, AS PART OF THEIR INTRODUCTION TO GENERAL SCIENCE.

Some simple experiments with water.

- (1) Water evaporates.
- (2) „ condenses. (Distillation, etc.).
- (3) „ contains bodies in solution.
 - (a) Solids (Food for Plants).
 - (b) Gases (Air for Fishes, etc.).
- (4) Water dissolves bodies.
- (5) Water freezes at a definite point. (Thermometer, etc.).
- (6) When water freezes, it expands—
 - (‘ Weathering of Soil,’ etc.).
 - (Importance on rivers and lakes, etc.).
- (7) Water boils at definite point.
- (8) Plants give off water vapour.
- (9) Roots take in water.
- (10) Plants will grow on water containing salts.
- (11) Thunderstorms. An experiment to illustrate.
- (12) A Rainbow. „ „ „ „
- (13) The Draining of Water through different types of soil.
- (14) The ‘ Lift ’ „ „ „ „
- (15) Water and Germination.
- (16) How Springs are formed.
- (17) Electrolysis of Water.

Other experiments relate to Air, Soil, and Life.

5. MEMORANDUM FROM DR. VARGAS EYRE: AN AGRICULTURAL PROJECT FOR TEACHING SCIENCE WITH WORKSHOP PRACTICE.

Introductory Explanation: Cultivation of Flax.

It must prove advantageous to have manual classes and science linked up in some way; to have them deal with a common subject. In that way one could provide the possibility of developing a craft concurrently with a knowledge of elementary science. By selecting a theme of general interest which a young child would know something about to begin with, it seems to me to be the most fitting manner by which to develop an interest in manual work and science. This would certainly give some opportunity and scope for the young mind having a latent desire for practical things—the very kind to prove of value in the colonies, and would not be detrimental to the pupils of the ordinary kind who are catered for almost exclusively.

Admittedly it is difficult to find a theme about which to weave a course of elementary science and at the same time provide opportunities for useful manual instruction. But if one could, it would meet to a considerable extent the difficulties of urban schools having no land. In any case the finding of such a theme and the working out of a system of teaching round the central idea seems to me to be the real problem before the schools at the present time. I have come to the conclusion that the old time flax industry provides such a theme and I submit the following skeleton course based upon simple knowledge of textiles, string, sheets, clothes, etc.

The Scheme.

Flax is a plant of unusual importance to man, being extensively used in the arts and manufactures, and many of its products find use in the home.

As a subject from which to develop elementary science and the use and construction of simple tools, it seems to be unique.

One could with little trouble develop a course of study and manual work—with flax and its products as the centre of interest with considerable educational advantage. For example:—

(a) Its rapid growth is an advantage, it takes barely 100 days from sowing the seed to plant maturity.

(b) Hand-made sections of the stem, with a low-power microscope, afford a splendid

example of plant structure; the re-inforcement of the stem by the bast fibres is particularly beautiful. For simple botanical instruction this is excellent material.

(c) The variations of colour and form of the flowers provide interesting examples for the study of heredity.

(d) The rapid development of oil in the seeds, the development of the cellulose fibres in the stem, their structure and significance, can all be shown simply.

(e) The root development may be observed in water cultures when a suitable solution is used. Its response to deficiency and excess of nutritive materials leads on readily to the idea of the nutritive requirements of crops, etc.

(f) The phenomenon of ripening of crops can be well shown with flax.

(g) The oil expressed from the seed, is the well-known linseed oil, the best drying oil—extensively used in the paint and varnish industry. This opens up questions of oxidation, soap making, hydrolysis, etc.

(h) The natural fermentation of the dried stems calls into play the naturally occurring organisms, and leads on to disease, sterilisation, etc. The organisms of flax retting are large and require but slight magnification to reveal them.

(i) The residue from the seed crushing provides the valuable cattle food known as linseed cake, and would lead on to consider feeding values, etc.

(j) The separation of the fibre from the dried straw after fermentation calls for the use of simple wood instruments, and of iron which any boy could make in the workshop.

(k) The fibre so separated may be cleaned by hand manipulation of very simple implements, all of which can be made by the pupil.

(l) The separated fibre from the straw warmed with dilute soda may be cleaned of adhering material, bleached by bleaching powder, and dyed any colour. This leads to discussion of oxidising agents: chlorine, lime, etc., and leads to the fibre constituting bleached linen.

(m) It is easy to hand-twist the unbleached fibre, if wetted, and so form thread, string and rope, the making of which are of interest to young people.

(n) It is but a short step to introduce the hand-weaving of fabrics—such as sacking from string, and cloth from thread, even if such be purchased.

At every stage represented by these paragraphs much home-made apparatus and appliances would be required and in the making of which constant demands would be made for manual instruction and in the use of tools.

N.B.—The above ideas are but the bare outlines, but probably sufficient is stated to suggest that through the co-operation of science and manual instruction on these lines they would make a better appeal to the young mind, and stimulate the interest of those of practical bent.

6. MEMORANDUM FROM MR. C. H. LOCKITT, HEADMASTER OF THE GRAMMAR SCHOOL, BUNGAY, EAST SUFFOLK.

At this school a Five-Years' Course in Science is arranged to include biological, geological, and agricultural interests. In the first year the work consists mainly of introductory scientific notions illustrated wherever possible from Nature: for example, the use of thermometers is studied in reading of soil temperatures. The second year is devoted to Biology; the course includes: the counting of bacteria in milk, testing the germinating power of seeds, the study of some plant diseases, and a certain amount of physiology of plants and animals. Before using the microscopes some time is spent on the elements of optics.

In the third year the main study is Chemistry, which is linked as far as possible to the biological knowledge—the study of compounds and mixtures leads naturally to the mechanical separation of soil constituents; of acids to a study of acidity of soils, and of its lime requirements; of nitrogen to the estimation of nitrates in the soil for which a colorimetric method is used, to the rotation of crops; phosphorus is taken in connexion with the phosphates of the soil.

In the fourth year the main subject of study is electricity and magnetism.

In the fifth year, that in which the School Certificate is taken, the syllabus of General Science which the Cambridge Syndicate have just introduced, sums up and completes the work of earlier years.

The main task of a rural school is to teach its farmer pupils what Science can do

for the future farmer whether at home or overseas, and so induce them to undergo subsequently a period of technical study for the industry.

As regards other subjects on the curriculum, English Literature is the same as that in any other school. In dealing with History a good deal of importance is attached to the history of the land, for it is found that country boys take an immense interest in, for example, the Agricultural Revolution of the Eighteenth Century, and in the Roman Agrarian system. A good deal of Geology comes into the Geography lessons, though at present some difficulty is found in working into the syllabus anything of the nature of systematic ecology.

7. SUGGESTIONS FROM A GIRLS' COLLEGE, SYDNEY, N.S.W.

The following extracts from an account of a girls' school at Croydon, near Sydney, N.S.W., written by the Principal, indicate some of the methods adopted to give girls an intelligent outlook on the world, particularly their own country, before they take their place in the world. The dominant note running through all the work and thought, is the connexion with life and its development, nationally, socially, and individually. The Principal writes, 'I am satisfied if girls leave the school with a realisation of some of the problems, and an inspiration to take some part in solving them.'

The Dalton Plan was introduced six years ago, and after being adapted to conditions, remains. Any change to the traditional methods of organisation the staff regards as unthinkable.

The development of the science teaching is towards a general science course, as it is held that a division of science into subjects in the early years gives a wrong impression, and has little to commend it.

The syllabus includes chemistry, botany, geology, and physiology for the first two years; physiology and either botany or geology throughout the five years.

In *Physiology*, practical work is insisted on, and a first-aid course; all practicable dissections are done individually, visits are made to medical school and hospital, particularly the Bacteriological Department.

Examples of assignments to show insistence on application, and typical of the school group work:—

1. A week's assignment was to examine the dietary of the boarders for a week; to determine whether it was suitable in respect of quantity and proportion; the class was formed in groups for weighing proteins, etc., and determined whether food consumed on the average was up to the requirements stated in text-books; finally, a report was drawn up by the leader embodying the conclusions and recommendations of certain small changes.

2. In *Chemistry* the work is almost exclusively practical, following as far as possible the direction suggested by questions which occur to the class, e.g. one class began by examining the fire extinguisher: the main interest at first was in carbonic acid gas. This led to a more or less full treatment of the gas. One line led to calcium bicarbonate and so to limestone caves: the Jenolan Caves are familiar, the correlation with geology was easy.

3. Another line led to the evolution of the gas by animal life, and the dependence of plant life on carbonic acid gas. Here correlation was made with botany and with the biological cycles of water, carbonic acid gas, and (less fully treated) nitrogen, leading at once to correlation with food lessons in physiology.

A further correlation was made with Domestic Science, the class being delighted at finding out why their cakes rise (or should rise).

Incidentally, the chemical similarity between egg shell and sea shells recalled the poultry yard. All these correlations were made by the pupils.

At this point the class returned to the examination of the fire extinguisher, and the question of the reason for certain metal being used. This led to the action of acids on metals, from which the transition to gases was natural—hydrogen proved a most interesting topic. The treatment of oxygen led back again to physiology, while a visit was made to a welding plant to examine the oxy-acetylene flame. And so on through the course, making it a natural following of inclination, not the following of a text book.

In *Biology*, a course of lessons is given during the last year (age 17). Stress is laid on the humanistic side. Topics dealt with: the origin of life, biological cycles,

basis of heredity, eugenics, leading biologists, the international nature of biology, the conquest of disease, the geographical distribution of diseases in Australia, both of men, animals, and plants (in this connexion films have been used dealing with liver fluke in sheep and hydatids), evolution, race divisions, insects and birds in relation to man, particularly in the country districts of Australia, community health, and so on. Finally, sex and reproduction are explained with *particular* reference to women.

In *Arithmetic*, books are almost dispensed with, as the great majority of arithmetic books are looked upon as almost valueless. Typical assignments are as follows:—

(1) Make up a budget of weekly expenses for a family of four on the basic wage (£4 5s. 0d.).

(2) Construct graphs to compare the growths of boys and girls up to 18 years in N.S.W. as regards height and weight.

(3) Make up the accounts of the expenditure and receipts in the cookery school.

In *History*, the course covered is World History from the dawn of the human race. One school project was a Historical Pageant in the school grounds showing the progress of man from nomadic times to the present-day League of Nations. This involved 400 characters in a three-hour performance. The present project is the construction of a chart (45 ft. by 4 ft.) showing the outstanding events of history with separate streams of communications, methods of agriculture, industrial expansion, dress, etc.

In *Economics*—an important subject—excursions are made to factories, welfare departments, Parliament, and Law Courts. One co-operative assignment last year was to inquire into the causes of the unrest in the Australian Shipping Industry. Last year a survey was undertaken of the conditions leading to the prosperity (or otherwise) of Australia under the following main headings:—

1. Population—age and sex elements. Distribution of population among the various industries and between town and country.

2. Detailed examination of the industries themselves. Wheat: areas, rainfall, increase and decrease from year to year. Markets. Possibility of new markets. Wool: distribution; varieties, how determined. Markets: possibilities for the future.

3. The effect of the tariff, *e.g.* on manufactured goods and agricultural implements.

4. Communications: volume of trade. Labour conditions. The trend of wages, comparing with index numbers. The Arbitration system. Strikes: their distribution through various industries in Australia during recent years. Time lost. All this demanded the collection of a mass of material from year-books and from individuals expert in different departments, the construction of charts and maps. This was done co-operatively, and throughout a continuous correlation with geography maintained.

Contemporary Events is made a major subject in the school course. The problem of World Reconstruction, the work of the League of Nations, China, India, South America, Afghanistan, Egypt, are some of the matters continually kept before the classes. Journals such as 'Current History' and the 'Round Table' are used besides the Daily Press, and such books as Philip Gibbs' 'Ten Years After,' etc.

Domestic Arts.—Cookery, Home Management, and Dressmaking are compulsory during two years of the course, and optional during others. Care of Infants is compulsory during the second and fourth years. As part of the course visits are paid to the baby clinics which are established in different parts of Sydney, and to kindergartens and creches.

Crafts are compulsory during the second year, and optional afterwards. The crafts taught have been: raffia, basket work, pyrography, batik, china painting, pottery and bookbinding.

School Gardens.—A portion of the school grounds has been laid out in gardens for the girls. Each form has a part allotted to it. The following is a type of experimental work carried out: a study of the sowing of plots of wheat, oats, barley, maize, and rye under different conditions.

1. Sowing at two periods—a month apart.

2. With two different kinds of fertilizer.

The aim is to give the girls an idea of the work that lies behind agricultural and horticultural practice.

School Camp.—A house is taken in the country with sufficient accommodation for a class. The school goes class by class accompanied by a Form Mistress, another

teacher, and the Domestic Science teacher for a week. A camp captain and committee are elected, these being responsible for the routine. The running of the house is the Domestic Science assignment. The assignments for the week are specially framed for practical work and excursions, *e.g.* :—

The History assignment is to work up from local sources the history of the district.

The Geography assignment requires them to inquire into the resources of the district, and to account for the existence of the town at that particular point. A map of the district is required, an excursion is also made to one of the big reservoirs for the Metropolitan Water supply and the catchment area mapped out.

An Arithmetic assignment includes the keeping of camp accounts, and calculation of expenditure for excursions. Those who are doing trigonometry are required to ascertain the heights of various outstanding hills.

The district is particularly interesting from a geological point of view, and as it is also well forested field work in botany was easy to find.

In connexion with Contemporary Events and Economics—the girls visit a farm colony near by where delinquent children from the city are being trained to become useful citizens. This is the starting point for inquiry into various methods of dealing with misfits in society.

A local butter factory also affords opportunities for inquiry into organisation, collection, and distribution of products.

One of the most important sides of the week's camp life is the social side, the organisation of which as far as possible is left in the hands of the girls themselves.

Much is of necessity omitted from the account of the many activities of this 'live' school—but it is hoped enough has been given to indicate how a school can be brought into contact with life, and how its science work can be made to subserve the needs of the girls, and not merely the demands of examiners.

The attitude towards external examinations is equally interesting. The Principal states that the great preponderance of professional opinion is against external examinations and that in reply to a questionnaire to the heads of the leading non-state schools, asking for opinion about the awarding of an Internal Certificate, fifteen out of eighteen regard the heads and staffs of approved schools as competent to award such certificates to their own pupils, and thirteen as against three thought that the public attached too much importance to the Public Certificate.

Secondary school work in N.S.W. begins at 12 plus ; an Intermediate Certificate can be taken at 15 plus, or just 16, thus allowing two years for a higher course to follow.

The practice at this school is to allow girls to sit for the Public Intermediate Certificate at the end of three years of secondary work if they wish to ; while the school gives an Intermediate Certificate based on a three years' course, on condition that the girl has taken an active part in school life, has shown a very satisfactory school spirit, and, in addition, has reached a satisfactory standard in six regular school subjects.

Formal Training.—*Interim Report of Committee* (Dr. C. W. KIMMINS, *Chairman*; Mr. H. E. M. ICELY, *Secretary*; Prof. R. L. ARCHER, Prof. CYRIL BURT, Prof. F. A. CAVENAGH, Miss E. R. CONWAY, Sir RICHARD GREGORY, Prof. T. P. NUNN, Prof. T. H. PEAR, Prof. GODFREY THOMSON and Prof. C. W. VALENTINE) *appointed to consider the Bearing on School Work of recent views on Formal Training.*

THE object of the Committee is to prepare an authoritative statement as to the disciplinary value of various elements in the curricula of the schools, about which much confusion of thought exists.

It is evident that, in the light of modern research, the extravagant claims made in the past for the unique value of certain subjects from the point of view of mental discipline, apart from their intrinsic value in the scheme of education, cannot be sustained.

In many schools an erroneous and extreme doctrine of Formal Training is still resulting in much wasted time and effort. An excessive amount of the time table is frequently devoted to subjects of relatively little importance with the main object of securing that mental discipline for the production of which they are imagined to possess special qualifications.

For this preliminary report the following special papers have been prepared which have been approved by the Committee:—

'Formal Training: the Psychological Aspect'...	Prof. Cyril Burt.
'Some practical Applications'	Prof. F. A. Cavenagh.
'Latin and Formal Training'	Prof. R. L. Archer.
'General and Special Training in the Application of Skill'	Prof. T. H. Pear.

In the second and final issue of the report, which it is hoped to present in 1930, Prof. T. P. Nunn will deal with a very important section, viz.: Mathematics and Formal Training; and other elements of the curriculum will be considered from the disciplinary point of view. An account will also be given of the experiments which have been carried out by Thorndike, Sleight and other workers on the subject of Formal Training.

FORMAL TRAINING: THE PSYCHOLOGICAL ASPECT.

By Prof. Cyril Burt, M.A., D.Sc.

The traditional view, known as the doctrine of 'mental discipline' or 'formal training,' assumes that the effects of mental exercise are general. It maintains that, by practising a mental capacity on some particular subject, we strengthen that capacity as a whole, and so improve its efficacy for any subject on which it may be employed in future. Thus, it has been claimed that the teaching of mathematics trains the powers of reasoning, so that the child becomes more logical, not only in dealing with other branches of the curriculum, but also in dealing with the problems of everyday life.

In the past this doctrine has been widely held among teachers and educationists; but during the last twenty years it has been severely criticised on the basis both of general theoretical principles and of experimental results.

The theoretical objections run briefly as follows: Mental processes, (those of memory, for example) do not depend upon simple capacities — 'faculties' lodged in some phrenological organ of the brain; and, even

if they did, we should have to conceive those capacities as already determined at birth and unalterable in after-life. Rather, it is said, the processes of the mind consist essentially in specific associations between definite situations and definite responses, these associations being due to the formation of particular nerve-paths within the brain. Clearly, the formation of one set of nerve-paths cannot influence the formation of another set of nerve-paths, unless they themselves are linked by similar associations.¹

The experimental studies have been numerous. They have dealt chiefly with such mental functions as memory, discrimination and manual dexterity, and with such educational subjects as arithmetic, grammar, geometry, science and Latin.² Two restrictions should be noted. First, in the experiments which endeavoured to isolate elementary psychological functions, it is important to realise that the investigators deliberately simplified the situation, and eliminated, so far as possible, emotional factors like interest or ambition: hence it is not always fair to apply direct to classroom conditions results obtained in the psychological laboratory. Secondly, the experiments on educational subjects have dealt almost exclusively with the influence of one school study upon another: they have not attempted to evaluate the effect of such studies upon the learner's interest, enjoyment and efficiency in after-life.

The position reached may be stated thus: No psychologist would doubt that under certain circumstances something very much like transfer of improvement undoubtedly takes place. Accordingly psychologists are now concerned rather to criticise the popular explanations of such transfer, and to deny that it occurs so freely and so widely as has previously been assumed. Hence in the most recent investigations the object has been, not so much to discover whether there is any such thing as a transfer of

¹ Compare Thorndike, *Educational Psychology*, vol. ii, pp. 359 and 418. Here I am concerned only to state the argument in its most definite form. Probably few psychologists in this country would accept the extreme associationist position as stated in the text. English psychology now teaches us that, if situation S is associated with reaction R, then, when a similar situation occurs in the form of S₂, it calls up not R but R₂, where R₂ : R :: S₂ : S. Thus, if the first bar of 'God Save the King,' heard in the key of B flat, becomes associated with the second bar in the same key, then, if a week later I hear the first bar in the key of C natural, I call up, not the original continuation in the original key, but an analogous continuation unconsciously transposed to the new key. This process, variously known as 'relative suggestion' or the 'eduction of correlates,' already implies a kind of transfer of training in the very process of association itself.

² For a recent summary of these experiments, see Whipple, *Twenty-seventh Year Book of the National Society for the Study of Education*, Part II, pp. 186-197; Sandiford *Educational Psychology*, pp. 279-289. Thorndike's elaborate investigations ('Mental Discipline in High School Studies' and 'A Second Study of Discipline in High School Studies,' *Journ. Educ. Psychol.*, xv. 1924 and xviii, 1927) deserve special mention as among the most elaborate and the most recent. His conclusion may be quoted: 'By any reasonable interpretation of the results, the intellectual values of studies should be determined largely by the special information, habits, interests, attitudes and ideals which they demonstrably produce. The expectation of any large difference in general improvement of the mind from one study rather than another seems doomed to disappointment. The chief reason why good thinkers seem superficially to have been made such by having taken certain school studies, is that good thinkers have taken such studies, becoming better by the inherent tendency of the good to gain more than the poor from any study.'

improvement, but rather to discover what are the factors and conditions that mediate or promote it.

The current view can be summed up as follows: Transfer of improvement occurs only when there are *common usable elements*, shared both by the activity used for the training and also by the activity in which the results of that training reappear. The more the influenced and the influencing activities resemble one another, the greater the influence is likely to be. Practice in subtraction will improve accuracy in division, because the latter involves the former, but it may have little or no effect on accuracy in multiplication. The study of Latin will aid the study of French, because many French words are derived from Latin roots, and because many of the methods of work used in learning Latin—*e.g.* the use of a dictionary—will also be required in learning French.

The 'common elements' may be elements of (i) material, (ii) method, (iii) ideal; they are most 'usable' when they are conscious.

In the laboratory experiments, it would seem that these common usable elements consist in a partial identity of material rather than of mental function. The fact that items of information, acquired during the training, can be usefully applied again in the subsequent tests is quite likely to produce an improvement in those tests as a result of the preceding training. On the other hand, the fact that the functions employed in both training and test are popularly called by the same name—'imagination,' 'observation,' 'memory,' or the like—is no guarantee that general improvement will be secured.

In the more concrete experiments dealing with school studies, it seems clear that the common usable elements may arise not only from partial identity of material, but also from a partial identity of method or procedure, and sometimes from a partial identity of ideal and aim. Hence it appears probable that in the schoolroom the most important agencies in transfer are such things as generalised attitudes and interests, generalised modes of attacking mental problems, generalised schemes of thinking, useful moral habits and serviceable maxims of logic.

These conclusions have been succinctly expressed by Prof. Godfrey Thomson and Professor Nunn: 'Transfer of training appears, to put it cautiously, to be much less certain and of much narrower spread than once was believed. Subjects of instruction will not therefore be included in the curriculum lightheartedly on the formal "discipline of the mind" argument. Other things being reasonably equal, useful subjects will have the preference.'³ 'We conclude that the training produced by an occupation or a study consists primarily in a facility in applying certain ideas and methods to situations of a certain kind, and in a strong tendency to bring the same ideas and methods to bear upon any situations akin to these.'⁴

The influence of conscious recognition has been made amply clear by recent experimental work. Here lies a principle which is of special interest to the teacher. A common element is more likely to be usable if the learner becomes clearly conscious of its nature and of its general

³ Thomson, *Instinct, Intelligence and Character* (1924), pp. 144-5.

⁴ Nunn, *Education: its Data and First Principles* (1920), pp. 210-211.

applicability: active or deliberate transfer is far more effective and frequent than passive, automatic, or unintentional transfer. This seems especially true where the common element is an element of method rather than of material, an ideal rather than a piece of information. Accordingly, when practice in reasoning about physical sciences improves the child's power to reason in biological sciences, this occurs not because his reasoning faculty as such has been strengthened, but because the habits and general notions of procedure which he has learnt in the first field are again consciously brought into play in the second field. Merely to practise a child in accuracy of scientific reasoning by quietly correcting his errors and merely repeating the exercises will not of itself produce any generalised power of reasoning logically; but if incidentally the child is encouraged to form an ideal of accuracy in reasoning, and to study its implications, he may try to live up to that ideal in every department of life.

It follows, therefore, that what chiefly assists the spread of training is not the mere perception of facts, but the perception of relations between facts: and this is something more than mere mechanical association. 'There comes first an unconscious employment of certain principles or ideals. These gradually become clearer and more definitely outlined. They are recognised by their owner and named, and thereby gain tremendously in effectiveness and in transfer-power. This recognition must, however, await the slow growth of the idea to be recognised. The teacher cannot put the words into the pupil's mouth—or rather, unfortunately, he can do so, but if he does it too early he will give mere words. . . . In general, the rule appears to be that any teaching which makes the pupil more conscious of how successful results are obtained is likely to assist transfer.' ⁵

The practical corollary is obvious. Teachers should arrange the work of their pupils and their own mode of teaching so as to lead their pupils to recognise clearly the methods by which efficient work is done. Further, it follows that the intelligent child, who can perceive relations spontaneously, who can generalise his methods and re-apply them on his own initiative, is likely to show a wider transfer than the dull child. With the dull the teacher can hope to do little more than implant specific memories and specific habits that will be definitely useful in and for themselves, and, so far as possible, impress upon the child how these memories and these habits may subsequently be applied.

Note.—Prof. Godfrey Thomson has read this paper and is in general agreement with the statement it contains.

SOME PRACTICAL APPLICATIONS.

By Prof. F. A. Cavenagh, M.A.

THE educational implications of the foregoing paper are clear. We can no longer retain any school subject solely on the ground that it provides 'mental discipline,' nor should we speak of the 'educative value' of a *subject*. Educative value exists not in the subject *per se*, but in the way

⁵ Thomson, *ibid.*, p. 143.

in which it is studied. It consists (to use another favourite expression) in 'learning how to think,' in forming interests or sentiments about a subject, and in building up such habits as perseverance, independent attack of problems, application of previous knowledge, etc. Any teaching which fails to foster such mental processes is uneducative, however much information it may succeed in driving in, and whatever examination results it may gain. Indeed, these considerations provide an additional argument against the dominance of examinations, since they tend to encourage either cramming, which can only induce the habit of further cramming, or spoon-feeding, which will produce habits of mental dependence, credulity, and inertia.

It cannot, however, be denied that a good deal of knowledge has to be acquired at school, either for the needs of life or as a basis for higher study, which depends largely on rote memory, and which cannot be taught in an 'educative' way. That is inevitable. But we should at least reduce such work to a minimum, and we should take care that everything which admits of intelligent teaching is so presented. Under present conditions teachers often avoid what they know to be the right method because it would take too long, and because the use of it would prevent them from covering the examination syllabus. After the examination the knowledge frequently vanishes; and as the children have not gained the desirable sentiments and habits their schooling avails them little in after life. It is no exaggeration to say that the modern mania for examination results not only wastes thousands of pounds of public money, but renders many recipients of secondary education less cultured and efficient than they might have been without it.

The same holds at the University level. An Honours graduate, if he is superior to a pass man, is superior not because of his greater knowledge, but because he has had less inducement to cram and more opportunity to get genuinely interested in his subject and to form conscious ideals of method. But a student who comes to the University with all the interest knocked out of him and with no habits of independent study, will certainly not take a high place in an Honours degree; hence the very disappointing record of many who enter with a 'brilliant' school record. And those who deal with post-graduate students must regretfully admit that the lecture-plus-examination methods of the modern university can be no less stultifying. And further, as teachers are largely recruited from the victims of these methods, the evil is perpetuated.

It thus appears that this generalised 'transfer' exists, and that it can cut both ways. If education consists in 'what remains after we have forgotten all we learnt,' it may be no more than a dislike and contempt for any serious mental pursuit, for anything 'high-brow.' On the other hand, it may mean activity of mind and the capacity for finding interest in any task and for constantly increasing the circle of one's interests.

If, as seems true, every subject can be studied in such a way as to create the right habits, then every subject can, on general formal grounds, claim a place in the curriculum. Selection will then depend on the intrinsic value of each subject; and this depends in turn on the probabilities and future needs of individuals. There are no absolute values,

and it is waste of time to argue as if there were. While everybody needs a certain humanistic basis, many cannot travel far on this line, but require scientific or technical subjects. The actual subjects are comparatively unimportant; any subject well taught will provide some beneficial 'transfer,' any subject badly taught will do harm.

THE DISCIPLINARY VALUE OF LATIN.

By Prof. R. L. Archer, M.A.

THE traditional claim of Latin to a large place in the curriculum for its disciplinary value has often suffered from three defects:—

(i) The range of the effect has not been defined. It has been alleged that it produces all-round 'accuracy,' whereas, if 'common usable elements consist in a partial identity of material,' the improvement must be largely confined to the use of language.

(ii) The stage which must be reached before the effect is produced has not been sufficiently defined.

(iii) The importance of the pupil's emotional attitude has been ignored.

If these points be taken into account, we believe that a limited but important claim for Latin can still be substantiated.

(i) Thomas Arnold, unlike many of his contemporaries, limited the effect to the use of language and particularly of the pupil's own language; and he attributed it largely to translation from the vernacular into Latin. Owing to the superior exactitude of Latin, it is claimed, a pupil who is intent on so translating a passage into Latin as to bring out its exact force has a stronger motive for analysing its precise meaning than can be secured by any other device. Such analysis becomes an unconscious habit, and, however dissimilar may be other situations which require an analysis of an English passage, the material (the English language) is the same. Latin prose thus isolates an element which appears in many situations and secures a definite objective in teaching, and it is this which is meant by formal training.

The history of modern languages further suggests that familiarity with Latin literature has affected their style. Sometimes this effect has been bad, *e.g.* when it produced excessive imitation of Cicero; but on the whole it has made for desirable elements in 'form,' such as the absence of exaggeration and emotionalism.

More doubtful is the claim put forward for Latin at its early stages that, as in deciding the form of a Latin verb you have to consider its conjugation, voice, mood, tense and person, and a mistake in any of them vitiates the result, a habit is set up of considering all relevant factors, in deciding *any* issue. One could not affirm that this result never occurs, but, as there is no identity (or even similarity) between the situation in which the habit is acquired and that in which it is hoped that it will operate, it is possible only if such care becomes a conscious ideal with considerable emotional strength.

(ii) Of the three possible effects which have been considered in the last section, only the unsubstantiated third could affect the early stages. The first appears valid, but the benefit begins only about the matriculation stage and applies to the abler pupils; that of the second begins even later.

The second is thus for specialists ; but the first establishes a claim for Latin as a part of general education for those who are likely to continue the study to the matriculation stage, if the answer under the next heading is favourable.

(iii) So little was the third point recognised that old-fashioned arguments almost suggested that it was the very uncongeniality of striving to be accurate which constituted the value. If the modern point of view be adopted, it becomes probable that many pupils have not enough of the general factor in ability (which appears to enter into the learning of Latin very considerably) to make sufficient progress to acquire the necessary desire for accuracy and the readiness to make the effort willingly. But this objection does not apply to matriculation candidates taught by an inspiring teacher.

The claim has thus been greatly reduced, but does not altogether disappear. Although much of our reasoning has taken place intuitively and without words before we throw it into language, throwing it into words is usually essential for ourselves and always for conveying the argument to others ; and the untrained mind often works out its arguments entirely in verbal terms and is at the mercy of language. Thus, in most subjects, accurate analysis of language is an indispensable factor, though only one factor, in accurate thought. On the other hand, it cannot be maintained that it is only through Latin that such power of analysis can be trained.

Note.—The claims of Latin for inclusion in the curriculum on the ground of its intrinsic value as distinct from its value as formal discipline are not considered in this paper. They constitute its strongest claim.

RELATION BETWEEN GENERAL AND SPECIAL TRAINING IN THE ACQUISITION OF SKILL.

By Prof. T. H. Pear, M.A., B.Sc.

POPULAR views concerning the relations existing between different skills are varied and conflicting. On the one hand a person is spoken of as 'clever with his hands,' 'good at games,' 'an all-round athlete.' On the other hand, the world's best exponents of any complex skills are usually very careful to be specialists, and there are even good grounds for the fear that the learning of a new complex skill, which superficially resembles a skill in which one is highly proficient, may actually be detrimental to the latter.

It is possible that both these views are justified. If we take the summary given below, as approximately representing the state of our knowledge concerning formal training, this may be illustrated.

No serious student of the subject denies that transfer from one acquisition to another *may* occur. But generally (a) the amount of transfer found in experiments is very much less than might have been naïvely supposed and (b) such transfer occurs in certain conditions which can be approximately specified. They are :—

(1) When common factors, of matter, of method, or of ways of approach exist, have been analysed out and recognised by the learner.

(2) Where an attitude of liking or disliking, welcoming or fearing, the new task, set up strongly in the one type of learning has been transferred to the other.

(3) Where a sentiment (*i.e.* a relatively permanent organisation of tendencies to emotion) has been acquired towards the work, or towards some person connected with the work, and is then transferred to the other type of learning.

It becomes clear that if this analysis be approximately correct, any two skills which superficially resemble each other (*e.g.* tennis and badminton, ski-ing and figure-skating), may contain (*a*) similar, even identical, elements which can be transferred bodily, and (*b*) completely antagonistic elements. From this it follows that habits learnt in the one type of skill may transfer 'positively' or 'negatively.' For example, while a figure-skater learns always to lean towards the direction of his turns, a ski-runner may have to lean either towards or away from the direction. An expert skater would find this very difficult to unlearn, while a novice at both sports would find less difficulty. Similarly, the oral learning of two foreign languages in the same year may cause interference.

Very little experimental work appears to have been done upon transfer as it relates to complex skills, *i.e.* 'integrations of well-adapted performances,' or even to the simplest cases of dexterity. But the results of experimental work carried out during the last three years in the Manchester laboratory⁶ seem to fit very well into this suggested view of transfer in general. In the experiments, there is an almost spectacular lack of transfer between habits which appeared to be very similar indeed. In some cases there is negative transfer owing to the interference of habits. Where transfer occurs it seems to be in terms of a general mental attitude.

If these results are confirmed by others, it would seem that we can never, on the basis of superficial inspection, believe that, because two skills look similar, acquisition of proficiency in one will transfer to the other. Where it does transfer, it may be as a result of common habits (though in such cases the risk of negative transfer is great), or of common material. Where positive transfer takes place it is more likely to occur through the agency of emotional attitudes, sentiments and ideals. The attitude of analysing movements, of demanding to know the reasons for them, the sentiments and ideals formed in connection with a particular teacher, or his method of regarding a certain skill, are probably the most powerful vehicles of transfer.

⁶ By Dr. C. E. Beeby, Mrs. L. Henshaw, Mr. J. N. Langdon and Miss P. Holman.

SECTIONAL TRANSACTIONS.

SECTION A. MATHEMATICAL AND PHYSICAL SCIENCES.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 427.)

CAPE TOWN.

Tuesday, July 23.

Prof. J. C. McLENNAN, F.R.S.—*Some Recent Experiments on the Structure of Matter at Low Temperatures.*

Prof. A. FOWLER, F.R.S.—*Standard Wave-Lengths in the Extreme Ultra-Violet.*

Measurements of spectra in the extreme ultra-violet can now be made with a degree of accuracy approaching those of spectra in the ordinary regions, and the establishment of standard wave-lengths has become a necessity. The paper gives the results of a comparison of the wave-lengths of certain lines of aluminium and silicon as determined by the coincidence method in different orders of the grating, and by calculation from series relationships.

Dr. J. S. VAN DER LINGEN.—*Spectroscopic Investigation of the Distribution of Yttrium in certain Cape Granites.*

Sir ERNEST RUTHERFORD, O.M., Pres. R.S.—*The Origin of Actinium.*

Dr. B. T. G. SCHONLAND.—*Some New Electrometers.*

GEOPHYSICAL DEPARTMENT.

Joint Meeting with Section E (*q.v.*) for communications on Geodesy and Surveying.

Wednesday, July 24.

Presidential Address by the Rt. Hon. Lord RAYLEIGH, F.R.S., on *Some Problems of Cosmical Physics, solved and unsolved.* (See p. 38.)

Mr. R. H. FOWLER, F.R.S.—*Thermionic and other Emissions of Electrons in the Light of Quantum Mechanics.*

The quantum theory allows us to calculate exactly the chance that an electron will penetrate any sort of hill or pass by any rapid step of potential energy. Taking any simple model of a metallic conductor which conforms to the quantum theory, for example, Sommerfeld's, which is Drude's modernised, we can calculate the rate of emission of electrons from the conductor (1) when the conductor is hot; (2) when it is cold, but subjected to a strong external field; and (3) the effect on the emissions (1) and (2) of surface impurities represented by certain reasonable changes in the

boundary field. These calculations seem to give a satisfactory account of the observed facts. The type of the formulæ obtained and the comparison with observation will be described in the actual paper.

Sir GILBERT WALKER, F.R.S.—*Dynamics and Sport* (with experiments).

Reports of Committees.

Thursday, July 25.

Prof. J. T. MORRISON.—*The General Circulation of the Atmosphere.*

Prof. W. DE SITTER.—*The Rotation of the Earth.*

Prof. A. S. EDDINGTON, F.R.S.—*Matter in Inter-Stellar Space.*

A survey is given of the present position of the problem of the cosmic cloud which is believed to pervade the whole galactic system. The direct observational evidence of its existence is afforded by the 'stationary' lines of calcium and rodium observed in the spectra of the more distant stars. These indicate a medium not sharing the individual motions of the stars. The different parts of it are nearly at rest relative to one another, except that the galactic rotation (found by Oort) affects the medium in the same way as the stars. Observational evidence is supplemented by a study of the physics of an extremely diffuse medium under the influence of the feeble radiation due to the stars. It appears that it will rise to a temperature not far short of that of the hottest stars, say 15000° . In such a medium condensations will occur at an average distance apart determined by the density. Taking the average distance of the condensations (diffuse nebulae) to be 150 parsecs, the density is 10^{-24} . If 1 per cent. of the cloud is assumed to be calcium, this gives just the right absorption to produce the observed strength of the stationary calcium lines. Various outstanding difficulties are discussed.

Prof. A. OGG.—*The Crystalline Structure of the Alkaline Sulphates.*

Dr. A. E. H. TUTTON, F.R.S.—*Significance of X-Ray Analysis of Alkali Sulphates.*

The X-ray analysis of the orthorhombic normal sulphates of potassium, rubidium, caesium, and ammonium is the result of a suggestion made in 1916 by the author to Sir William Bragg, and was undertaken by A. Ogg and F. Lloyd Hopwood, with crystals supplied by the author. It has since been amplified by Ogg at the University of Cape Town. Simultaneously with the latter work, W. Taylor and T. Boyer have investigated the structure of caesium and ammonium sulphates, with crystals also supplied by the author, and have obtained practically identical results. All agree that the structure is based on the simple orthorhombic space-lattice No. 10, with four molecules R_2SO_4 to the rectangular unit cell, and that the detailed structure conforms to the space group V_{16}^a . The positions of the metallic alkali atoms have been located as well as those of the tetrahedral SO_4 groups, in which the S-atom forms the centre of the tetrahedron while the four O-atoms occupy the corners. The NH_4 group is also found to be tetrahedral, with the N-atom at the centre of the tetrahedron and the four H-atoms at the corners; moreover, the NH_4 group has been shown to replace the alkali metallic atom so perfectly that in the case of the middle element rubidium it fits exactly into the same space. Further, the absolute lengths of the edges of the rectangular cell have been obtained for each of the four salts, and thence the absolute cell-volume.

Now it is of the highest importance that these concordant results of different investigators confirm perfectly the values for the relative dimensions of the unit cells, the 'topic axial ratios,' which were published long ago by the author. They further confirm the extraordinarily close isostructure, the equality of cell volume, of the ammonium and rubidium salts, which had been pointed out by the author, and which

had formed his reason for non-acceptance of the interesting valency volume theory of Pope and Barlow, according to which the cell-volume of ammonium sulphate should be double that of rubidium sulphate. Again, these X-ray results agree absolutely with the law of progression of the crystal angles, constants, and properties, with the atomic weight or atomic number of the interchangeable elements, which has been found universally to apply in the cases of eutropically (interchanges only within the same family group) isomorphous substances of strictly analogous structure-type. This law has been perhaps the main results of the author's forty years of research, during which not only these simple sulphates of the alkalis, but also the corresponding selenates, which afforded precisely analogous results, and seventy-four double sulphates and selenates of the monoclinic hexahydrated series, have been investigated. In these latter more complicated substances the alkali sulphate or selenate is combined with the sulphate or selenate of Mg, Zn, Fe, Mn, Ni, Co, Cu, or Cd, and the crystals thus afforded sixteen times over independent results for the interchange of the alkali metals. Moreover, the author has likewise completed a similar investigation of the perchlorates of the alkali metals K, Rb, and Cs, and of ammonium. In all these cases the results were perfectly similar.

Hence, a general law has been shown to hold, that in any unbroken strictly structurally comparable series of eutropically isomorphous compounds, the whole of the crystallographic morphological and physical properties are functions of the atomic numbers or weights of the interchangeable family-group elements which give rise to the series. All apparent exceptions, such as the alkali halides, have been proved to be cases of broken and non-comparable series.

Finally, this law of progression is shown to be due to the progressive change in the structure of the atoms themselves, eighteen electrons, in one or two complete shells, being added when potassium is replaced by rubidium, and again when the latter is replaced by caesium.

DEPARTMENT OF COSMICAL PHYSICS.

Mr. E. N. GRINDLEY.—*Recent Results of the Magnetic Survey of South Africa.*

Sir FRANK DYSON, F.R.S.—*Proper Motions in the Greenwich Astrographic Zone.*

By comparison of recent photographs with those taken about 28 years ago proper motions have been determined of a very large number of stars. Analysis of the results shows the streaming in two directions of these stars, and the numbers in the two directions are equal. The mean parallaxes of these stars in different galactic latitudes are given and their mean peculiar velocities.

Mr. H. C. MASON.—*Lunar Craters and the Volcanic Theory.*

Friday, July 26.

Prof. W. H. ECCLES, F.R.S.—*The New Acoustics.*

Prof. A. M. TYNDALL.—*Some Problems relating to the Mobility of Gaseous Ions.*

The paper deals with the following topics: (1) Established results. (2) The difference between positive and negative mobilities. (3) The effect of vapours. (4) Mobility in pure gases. (5) Positive ions of short age. (6) Suggestions as to future progress.

Sir T. MUIR, F.R.S.—*The Literature of Cayleyan Matrices.*

Mr. H. HORROCKS.—*The Recent Spectrum of Nova Pictoris.*

Dr. H. SPENCER JONES.—*Elements of the Moon's Orbit and the Solar Parallax from Occultations 1753–1908.*

JOHANNESBURG.

Wednesday, July 31.

Rt. Hon. Lord RAYLEIGH, F.R.S.—*The Fluorescence of Mercury Vapour.*

This paper deals with fluorescence excited by frequencies equal to or less than that of the resonance line λ 2537.

It is known that unexcited mercury vapour shows an absorption band beginning very near the resonance line, and extending towards the red as the density increases. In 4 inches of denser vapour it can even be extended as far as λ 3750, or more than 1200 Å.

It is found that green fluorescence can be observed with excitation at any part of this band, from the resonance line to at any rate λ 3450. In all probability only technical difficulties hinder our going further still.

The fluorescence excited consists of four distinct features :—

(a) The resonance line λ 2537.

(b) The narrow band 2540, near the resonance line.

(c) The broad structureless emission band λ 3130 to λ 3650 not known in absorption.

(d) The structureless visual band.

When excitation is applied as far towards the red as practicable, *the band c is emitted entire*, in spite of the fact that excitation is only applied at the middle of it. Stokes' law is notably violated, the 'anti-Stokes' effect extending 230Å° towards shorter waves.

As regards features *a* and *b*, so far as the available evidence goes these are only excited when the excitation is quite near the resonance line. They can, however, be excited by frequencies definitely less than that of the resonance line.

When excitation is applied by a continuous source broader than the resonance line, it is possible to distinguish a discontinuity in the visual fluorescence. If the pressure of the fluorescent vapour is a few centimeters, the emission due to the *core* of the resonance line (core effect) extends only a fraction of a millimeter from the wall of the vessel. As we proceed inwards from the wall of the vessel there is a discontinuity of intensity, the emission becoming suddenly less, and stretching for several centimeters without much further loss of intensity. This latter is due to absorption outside the core of the resonance line and I call it the *wing* effect. But it probably extends to the limit of absorption (λ 3750, say), no further discontinuity having been so far recognised. The breadth of the core of the line was determined from this effect as 0.1Å°. It is considered probable that the *core* effect represents *atomic* absorption and the *wing* effect *molecular* absorption. The same discontinuity of intensity appears by photography through filters which transmit the spectral features *a* and *b* while suppressing *c* and *d*.

Both the core effect and the wing effect, as observed visually, move down stream from the point of excitation when the vapour is in rapid motion. The visual wing effect certainly, and the visual core effect probably, show a time interval between excitation and fluorescence.

The photographic fluorescence (features *a* and *b* blended) lasts a much shorter time than the visual. It is possible so to adjust the velocity of the vapour stream that the visual effect extends several centimeters down stream, while the photographic effect remains sensibly stationary. This applies both to the wing and the core effect.

But, what is remarkable and unexpected, both the photographic wing effect and the photographic core effect can be observed to move conspicuously down stream in a sufficiently rapid blast.

Special interest attaches to the photographic core effect at low pressures. Under these conditions there is no visual effect, and the photographic effect is apparently limited to the resonance line. Thus the band features *b*, *c* and *d* are all absent, and we have only the resonance line *a*. In this case, therefore, we have all the characteristics of what is called *resonance radiation*, discovered by R. W. Wood in 1912. But, contrary to received views, it is here found to last long enough to be propagated some centimeters down the vapour stream from the point of excitation. This implies a duration of the order of 10^{-4} seconds, yet other methods of investigation indicate that the atom only remains in the excited state for 10^{-7} seconds. The reconciliation of their discrepancy has not yet been found.

Dr. S. M. NAUDÉ.—*The Quadruplet Structure of the Spark Spectrum of Mercury, Hg II.*

By means of a direct current discharge with 1,600 volts in a tube which was provided with a hollow carbon cylinder as cathode and contained mercury in the presence of helium, Paschen has recently produced and analysed the ordinary spark spectrum of mercury. By choosing a larger cathode and using 5,000 volts D.C., it is possible to maintain a steady discharge in pure mercury vapour which is continuously produced by the heat from the glowing cathode. The spectrum so produced has been photographed with glass and quartz Hilger spectrographs, a one and a half metre concave grating and a one-metre vacuum spectrograph. On the basis of the $(5d^96s^2)^3D_{3,5/2}$ ground terms discovered by Paschen, twenty new terms have been found belonging to multiplets which have the quadruplet structure; these are compared with the copper arc spectrum. The terms obey the rules developed by Pauli, Heisenberg and Hund. The excitation potentials of various lines calculated from the term scheme, compare satisfactorily with measurements by direct impact of electrons made by Déjardin.

Prof. S. CHAPMAN, F.R.S.—*A Theory of the Equilibrium and Changes of Atmospheric Ozone.*

Dr. F. W. ASTON, F.R.S.—*Recent Work on Mass Spectra.* Followed by Discussion on *Atomic Nuclei*.—Sir ERNEST RUTHERFORD, O.M., Pres. R.S.

Thursday, August 1.

Dr. EZER GRIFFITHS, F.R.S.—*Some Aspects of the Research Work of the National Physical Laboratory, England.*

The paper describes with numerous illustrations recent research at the N.P.L. on industrial problems and in the development of instruments.

The purposes for which the Laboratory was founded were (1) to carry out research, especially research required for the accurate determination of physical constants and for the maintenance of standards; (2) to make tests on instruments and materials; and (3) to carry out special investigations for Government Departments and private firms.

Whilst models are used for investigations in connection with the lighting of picture galleries, the acoustics of public buildings, and the design of ships and aeroplanes, especial attention is given to the translation of the data to full scale by actual observations on the full-sized structure and by theoretical work based on the Principle of Similitude.

In instrumental equipment the application of interferometer methods is illustrated by apparatus for the testing of camera lenses and telescope objectives, block gauges for length measurements and the mode of vibration of piezo-electric quartz oscillators.

The methods employed for the establishment of the scale of temperature in the range -200° to $+3000^{\circ}$ C. and the determination of the electrical units are outlined.

Mr. A. C. MENZIES.—*The Raman Effect: a Short General Account.*

Sir GILBERT WALKER, F.R.S.—*Meteorology in Application.*

Joint Discussion (Sections A, B) on *Quantitative Chemical Analysis by X-Rays and its Applications*.—Prof. G. HEVESY.

A method has been worked out by which minerals and alloys can be quantitatively analysed without the use of chemical processes. A known amount of reference substance is added to the substance to be investigated and the intensity of the emission X-ray spectra of the two substances excited by X-rays is examined. In this way practically any element in a mineral can be determined in a few hours, provided the proportion present is more than one in ten thousand. The method is particularly

useful in determining the abundance of the rarer elements in the earth's crust and in meteorites. This method combined with chemical concentration was used in the case where the proportion of the element is less than one in ten thousand.

DEPARTMENT OF COSMICAL PHYSICS.

Dr. H. KNOX-SHAW.—*Hornsby's Meridian Observations at the Radcliffe Observatory, Oxford.*

The reduction of these observations, which has been proceeding during the last four years with the collaboration of Dr. J. Jackson, is nearing completion. Attention has been concentrated on the two periods 1774–1784 and 1790–1798. The observations in Right Ascension of the Sun and ninety-one standard stars have been reduced; those of the Moon and Planets have been done for the first period, but with few exceptions they await the computation of tabular places for comparison. The work on the Declinations is much less far advanced, but it is hoped to be able to give definitive results for one period.

The R.A. observations of the sun indicate progressive changes amounting to 3" in the sun's longitude as compared with Newcomb's tables, but until this can be checked by the observations in declination it must be received with caution. Those of the stars confirm Boss' system of proper motions rather than those of Eichelberger as regards variation both with right ascension and with declination.

Prof. W. DE SITTER.—*Satellites of Jupiter.*

Dr. W. T. LUYTEN.—*The New Grootfontein Meteorite.*

Friday, August 2.

Prof. A. FOWLER, F.R.S.—*The Spectra of Carbon, Nitrogen, Oxygen and Silicon at successive stages of Ionisation.*

Lines of these elements appear prominently in the spectra of the hotter stars, and their correct assignment to atoms in various stages of ionisation is of importance in theoretical discussions of stellar atmospheres and in the interpretation of the spectra of nebulae. The paper gives an account of some of the experimental methods by which the lines emitted as an atom loses successive electrons can be identified to some extent, and of the way in which analysis of the spectral structures completes the identifications. In accordance with Bohr's theory, the Rydberg constant, designated by R for neutral atoms, becomes successively $4R$, $9R$, $16R$... when one, two, three... electrons respectively have been removed by the exciting agency. As the series constant increases, the principal lines occur with shorter wave-lengths, and their investigation requires the use of the vacuum spectrograph. In the frequent absence of sufficient data for the calculation of the series constant, the regular and irregular doublet laws, as shown by Millikan and Bowen, provide a valuable aid in the classification of the lines. The final results for applications to stars are expressed in the form of ionisation potentials corresponding with the various spectra, or as excitation potentials for individual lines.

Mr. R. H. FOWLER, F.R.S.—*The Application of Prof. A. Fowler's Experimental Data to Astrophysical Problems.*

The various spectra of Si, C, N, and O are specially important in the study and classification of the B and O type stars, which are the hottest types known to us. The maxima of the lines of these spectra which are fixed by analysis of the stellar spectra enable the temperatures of the corresponding stellar atmospheres to be roughly deduced. This work is described, and also more recent work by Prof. Milne which has greatly improved the theoretical basis. A temperature scale of B and O type stars is given which is based on the latest theory. The interesting problem of the origin of the so-called nebulum lines is also discussed, as they appear to be lines of O and N not emitted under ordinary conditions.

Mr. W. M. H. GREAVES.—*The Colour Temperature of Early Type Stars.*

The observational methods used in determining colour temperatures by measures of the optical densities of photographed spectra are described briefly in this paper.

It is shown that by stellar observations alone the quantity $k - \frac{C_2}{T} \left/ \left(1 - e^{-\frac{C_2}{\lambda_m T}} \right) \right.$

can be determined for each star where k is a constant, T is the colour temperature, C_2 ($=14320$) is the well-known constant in Plunck's formula, and λ_m (measured in microns) is the mean wave-length of the spectral range used. The constant k can only be determined by spectro-photometric comparisons of one or more stars with a terrestrial source.

The observations which have been obtained for early type stars give temperatures which in many cases conflict with those predicted from the ionisation theory. Most stars of type O and many stars of types B0 to B2 have colour-temperatures lower than the average star of type A0, whereas the ionisation theory leads us to expect considerably higher temperatures for the O and B type stars. Two possible explanations are suggested: viz. (1) a reddening of the star light by passage through an interstellar cloud, and (2) considerably reduced pressures in the reversing layers.

Dr. H. L. ALDEN.—*Programme of the Yale Southern Station.*

Dr. DOROTHY WRINCH.—*Generalised Solutions of Laplace's Equation.*

A large class of problems in mathematical physics require for their solution the construction of a function V which satisfies Laplace's equation

$$\nabla^2 V = 0$$

is evanescent on S the sphere at infinity, has no singularities between S and a certain closed surface s , and on this surface takes a specified form. This general class includes problems of electrostatics, such as the distribution of electricity on conductors, both when they are freely charged and when electrification is due to an external field of force and problems of hydrostatics, as for example when there is streaming past an obstacle or when the surface in question has uniform translational or rotational motion in an infinite fluid.

In this paper the author explains a method of constructing a harmonic function V to solve problems associated with surfaces of revolution s of various types. Problems associated with spheroids (already, of course, soluble in terms of spheroidal harmonics) yield more easily to this technique, and problems associated with surfaces of revolution whose generating curves are nodeless epicycloids of retrograde type given parametrically by

$$\begin{aligned} x &= a (\cos u + k \cos 2u) \\ y &= a (\sin u - k \sin 2u) \end{aligned} \quad 0 \leq u \leq \frac{1}{2}$$

which range from the circle for $k=0$ to the three-cusped hypo-cycloid for $k=\frac{1}{2}$ admit simple treatment on these lines.

The essential point of the method is that it allows the construction of harmonics suitable for a large variety of surfaces of revolution. The author will give some further examples of surfaces of revolution to which it is applicable.

Mr. F. PURYER WHITE.—*Clebsch's Contact Problem.*

The problem deals with the configuration of the sets of $p-1$ points upon an algebraic curve of genus p which, each counted twice, make up a canonical set, and which are thus the points of contact of the curve with a primal in the space considered. If the curve is the most general of its genus we may take it to be the canonical curve of order $2p-2$ in space of $p-1$ dimensions; and the problem is that of determining the $(p-1)$ -tangent primes. The theory of the Riemann theta function provides a certain amount of general information with regard to this case, e.g. the number of such primes is $2^{p-1} (2^p - 1)$, but from the geometrical point of view the only case which has been completely worked out is the first, $p=3$, the bitangents of the plane quartic curve.

In this paper a survey is given of recent work, notably that of W. P. Milne, for the cases $p=4, 5$. Another case, which is not general in the sense described above, arises with the plane quintic curve ($p=6$). Here we have to investigate the 5-tangent conics. Some progress can be made on the lines of two methods which have proved successful for the quartic, Hesse's discussion by means of a net of quadrics and Geiser's generation from the cubic surface.

SECTION B.—CHEMISTRY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 427.)

CAPE TOWN.

Tuesday, July 23.

Presidential Address by Prof. G. BARGER, F.R.S., on *The Relation of Organic Chemistry to Biology* (followed by Discussion). (See p. 51.)

Wednesday, July 24.

Prof. B. DE ST. J. VAN DER RIET.—*Volatile Oils from South African Plants.*

The volatile oils from (a) non-indigenous plants, particularly those from the oleo-resin of the cluster pine, *Pinus pinaster*, and the citrus, and from (b) indigenous plants have been investigated, and in some cases their constants determined. Of the latter class some seventeen varieties have been dealt with, and the desirability of a more complete investigation is emphasised.

Dr. E. SEMMENS.—*Chemical Effects of Lunar Radiation.*

The hydrolysing effect of moonlight is shown by its action on films of boiled starch. By treating with iodine the faint shadow of a small opaque object can be printed on paper dipped in starch solution, which has been exposed to the lunar rays.

This effect is also seen when the surface of a leaf is similarly treated. The phenomenon is most evident at times of maximum polarisation of the lunar radiation.

The action is entirely a surface one, and is due to some correlation between the orientation of the polarised light vibrations and that of the surface molecular layers of the starch film, or of the physiological surface.

This correlation was first suggested by the author at the Liverpool meeting in 1923 in connection with the effect of polarised light on starch grains.

The fact of the hydrolysis of starch and of other higher organic compounds affords an explanation of many of the observed effects of moonlight and of some of the so-called 'superstitions.'

The significance in connection with agriculture, timber-felling, &c., is discussed.

Dr. N. V. SIDGWICK, F.R.S.—*Chemical Linkage.*

Thursday, July 25.

Prof. J. SMEATH THOMAS.—*Germanium Imide.*

In the experimental work described here Dr. W. Pugh and W. W. Southwood collaborated.

In a previous communication the product of the interaction of ammonia with germanium tetrachloride was described. It was given the formula $\text{GeCl}_4\cdot 6\text{NH}_3$, and it readily takes up ammonia under pressure, forming a liquid having the formula $\text{GeCl}_4\cdot 6\text{NH}_3$.

It was privately suggested by Dr. Franklin that the substance $\text{GeCl}_4\cdot 6\text{NH}_3$ might in reality be a mixture of $\text{Ge}(\text{NH})_2$ with NH_4Cl . This view is supported by the fact that the substance has a very small ammonia pressure at ordinary temperatures. The addition of ammonia also confirms it. NH_4Cl is known to add three molecules NH_3 , forming a compound of dissociation pressure, variously given but in the neighbourhood of 1,040 mm. at 0°C per cent. This is the dissociation pressure of $\text{GeCl}_4\cdot 16\text{NH}_3$. A mixture of $\text{Ge}(\text{NH})_2$ with $4\text{NH}_4\text{Cl}$ should take up 12 molecules of NH_3 against the 10 molecules found. It is suggested that the $\text{Ge}(\text{NH})_2$ acts for this purpose like 2 molecules NH_3 .

From the substance $\text{GeCl}_4\cdot 6\text{NH}_3$ the imide was isolated by dissolving out the NH_4Cl with liquid NH_3 . Owing to the extremely hygroscopic nature of the imide it was difficult to obtain a pure specimen. By carrying out the preparation and the weighing for analysis in an enclosed vessel a fairly pure specimen was finally obtained.

The action of heat and of the gas on the mixture of germanium imide and ammonium chloride has been investigated.

Alkyl substituted imides have also been obtained by the action of primary and secondary amines on germanium chloride. Tertiary amines do not react with this substance.

From the products of the hydrolysis of the substituted imides thus obtained it is concluded that the structure of germanium imide is $\text{Ge} \begin{smallmatrix} \text{NH} \\ \text{NH} \end{smallmatrix}$ and not $\text{N} \equiv \text{Ge} - \text{NH}_2$.

Prof. J. SMEATH THOMAS.—*Recently discovered Nitrate Deposits in South-west Africa.*

The deposit referred to in this communication occurs in the Gibeon district of S.W. Africa. The geology of the arid area lying to the east of the railway from Keetmanshoop to Marienthal is briefly as follows. On the Upper Dwyka deposits rests a layer of roughly 500 feet in thickness of Ekka shale mixed with some limestone, and this in turn is covered by a band of hard calcareous rock containing quartz pebbles varying in thickness from 50 feet to almost nothing. This calcareous deposit is covered by sand to varying depths, and it stretches away from the Fish River valley in which the railway runs towards the Kalahari.

The calcareous rock is cut through by three rivers, roughly parallel with the Fish River, namely the Auob, the Elephant and the Nossob rivers, and the river valleys are marked by a series of low cliffs of the calcareous rock. The first discovery of sodium nitrate was made at Witkranz in the Auob river valley lying roughly 50 miles east and slightly north of Marienthal. Since then it has been found in the cliffs for many miles along the Auob river and also in similar cliffs along the Elephant and Nossob rivers. The area thus covered is between 30,000 and 40,000 square miles.

Upwards of five hundred specimens have been taken at wide intervals along all three valleys, and practically all contain sodium nitrate. The specimens are of two kinds: (1) specimens of rock from the cliffs face—these are to some extent weathered; (2) specimens from the talus at the foot of the cliffs.

These are obviously enriched secondary deposits. The first type contains sodium nitrate in varying amounts from 1 to 23 per cent. The second type is much richer, and specimens containing 90 per cent. NaNO_3 have been examined. Sodium chloride is also present in considerable amount, but iodates appear to be absent.

No investigation beyond this superficial examination of the cliff face and the talus has yet been undertaken. The value of the deposits will depend on whether (a) the calcareous rock as a whole contains nitrate, (b) the nitrate content increases as one recedes from the cliff face.

There is a good water supply available from artesian wells, which at present yield 10,000,000 gallons per day along the Auob river.

Friday, July 26.

Joint Discussion with Section I (*q.v.*) on *Vitamins*.

Prof. K. FREUDENBERG.—*The Vegetable Tannins.*

The constitution of only two large groups, the gallotannins and the catecholtannins has been completely determined by decomposition and synthesis. To the class of

gallotannins belong the tannins of gallnuts from the different species of oak and sumach. The catecholtannins, derived from catechin, consist of the catechu- and gambier-tannins, quebrachotannin, &c. The chief properties and uses of these tannins are discussed.

In the case of other tannins, those of the Middle European oak, the mangrove, the South African sumach from osyris, the cinchona bark, &c., which have been closely investigated, not even the group classification is known. They have, however, certain constitutional features and properties in common on which their industrial uses depend.

The rôle of each tannin class from the standpoint of plant physiology is discussed. There is the possibility of a relationship between gallic acid and the sugars and the established relationship of catechin to the sap-soluble pigments of the flavone group and to the anthocyanins indicate their connection with the respiration process.

The general behaviour of all tannins in plants is the same. Being formed mostly in the leaf cell, they must pass through the membranes in a lower molecular form before being finally deposited in the galls, bark and wood. In the case of the hydrolysable gallotannins this is possible through the hydrolysis products, gallic acid and sugar, which can then reform the gallotannins by condensation. In the case of the non-hydrolysable catecholtannins, the only possibility is for these to be formed from catechin itself, which can pass through the membranes and form the complex catecholtannins later. It is possible that this primary stage of the catecholtannins may be found in the leaves.

JOHANNESBURG.

Wednesday, July 31.

Mr. H. A. WHITE.—*The Chemistry of Gold Extraction.*

The reactions utilised in the extraction of Gold from Banket Ores by the Cyanide Process are briefly discussed and each step in the treatment from the stopes to the Residue Dumps is described from the point of view of the Chemistry involved therein.

Prof. M. RINDL.—*A Crystalline Alkaloid from the bark of Strychnos Henningsii.*

Whilst the bark of most strychnos varieties is poisonous that of *Strychnos Henningsii* is either non-toxic or only slightly so. It contains between 5 and 6 per cent. of alkaloid, and is 'reported as being used by the natives of Eastern Pondoland as an appetiser-bitter extracted in alcohol.' It is also reputed to be endowed with medicinal virtues. It is known locally as the 'hard pear tree.'

On the initiative of the Forest Department of the Union an investigation into the active constituents of the bark was begun at the Imperial Institute, South Kensington, in 1913, by Mr. A. E. Andrews, but had to be abandoned before completion on account of the war. Whilst he could obtain the bulk of the alkaloid only in the form of a resin, he succeeded in isolating a small amount of a crystalline base. The investigation was continued by the author with fresh supplies of plant material.

It transpired that there was some doubt about the botanical identity of the original plant material as it had been ascertained in the meantime that a species, *Strychnos mitis*, which is closely allied botanically to *S. Henningsii*, occurs commonly in the indigenous forests of South Africa. Supplies of *Strychnos mitis* bark were accordingly obtained, but proved to be practically devoid of any constituents of an alkaloidal nature. Repeated attempts to obtain further supplies of the alkaloid originally isolated by Andrews ended in failure. Success was finally achieved with bark collected at approximately the same period as that originally sent to the Imperial Institute, and the suggestion is put forward that seasonal variations may account for the presence of the alkaloid in some consignments of the bark and its absence in others. The crystalline alkaloid is obtained by repeatedly shaking an acid aqueous solution of the total alkaloids with chloroform. It is gradually and seemingly continuously removed from the solution by this method, indicating feeble basicity.

It melts at 280.5–282° C., is not alkaline to litmus, crystallises from alcohol in tabular crystals of the rhombic system and gives characteristic colour reactions with

concentrated nitric acid and ammonia. Four alternative formulæ are suggested, namely, $C_{20}H_{31}N_2O_3$, $C_{20}H_{32}N_2O_3$, $C_{21}H_{31}N_2O_3$, and $C_{21}H_{32}N_2O_3$. It is not identical with strychnine or with any of the known strychnos alkaloids, and is apparently a new compound.

Prof. G. H. STANLEY.—*The Composition of some Prehistoric South African Bronzes, with Notes on the Methods of Analysis.*

This paper puts on record in tabular form the results of chemical analysis and microscopic examination of over 30 examples of S. African pre-historic bronzes, coppers and tins.

The special methods of analysis necessitated by the small quantities of sample usually available are also described.

Thursday, August 1.

Mr. A. C. G. EGERTON, F.R.S.—*The Influence of Antiknocks on the Combustion of Hydrocarbons.*

The theory that antiknocks have their specific effect during the early stages of the inception of combustion by the interruption of the chains of reacting molecules, which has been derived as a result of experiments by Egerton and Gates on the ignition and on the detonation of various mixtures, is further supported by the theory of combustion advanced by Semenoff and, in greater detail, by Thompson and Hinshelwood.

The effect of pressure on temperature of ignition can be explained in terms of such chain mechanism; branching of the chains explains the sudden acceleration of rate of combustion resulting in ignition. Some experiments on the ignition points of hydrogen, carbon monoxide and hydrocarbons illustrate this point.

The effectiveness of various antiknocks are compared by means of a Delco engine designed for the purpose, and the results are reviewed in terms of the above theory.

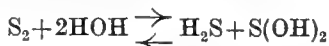
Joint Discussion with Section A (q.v.) on *Quantitative Chemical Analysis by X-Rays and its Applications.*

Friday, August 2.

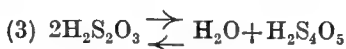
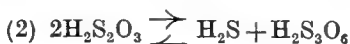
Prof. H. BASSETT and Mr. R. G. DURRANT.—*The Inter-relationships of the Sulphur Acids.*

The hydrogen ion concentration plays a very important part in all reactions of the sulphur acids and in great measure determines the path followed. Addition of acid favours reactions which remove hydrogen ions, in accordance with the principle of Le Chatelier, whilst alkali produces exactly the opposite effect.

Hydrolysis of sulphur according to the reaction—



and three alternative modes of decomposition of thiosulphuric acid are the key reactions in the chemistry of the sulphur acids. Of these three modes of decomposition



the second is of the most interest in connection with the polythionic acids. Trithionic acid is the primary thionic acid both in the Wackenroder reaction and in the decomposition of thiosulphates by acid. The higher thionic acids are formed from trithionic acid by addition of sulphur, the chief sulphurising agent being thiosulphuric acid.

Prof. H. BASSETT.—*The Cobalt Chloride Colour Change.*

In 1902 Donnan and Bassett (*Trans. Chem. Soc.* 81, 939) showed that red cobalt chloride solutions contained a red cation while blue solutions contained a blue anion. A phase rule study of the systems $\text{CoCl}_2\text{—HCl—H}_2\text{O}$, $\text{CoCl}_2\text{—MgCl}_2\text{—H}_2\text{O}$, $\text{CoCl}_2\text{—HgCl}_2\text{—H}_2\text{O}$ and $\text{CoCl}_2\text{—ZnCl}_2\text{—H}_2\text{O}$ has now been made to try and determine the precise nature of the red and blue ions present in the several solutions.

From the nature of the crystalline compounds which have been isolated it is concluded that in cobalt chloride solutions there may exist, according to the prevailing conditions, the red cations $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Co}(\text{H}_2\text{O})_4]^{2+}$ and possibly $[\text{CoCl}(\text{H}_2\text{O})_5]^+$ and the blue anions $[\text{CoCl}_4(\text{H}_2\text{O})_2]^-$, $[\text{CoCl}_4]^{2-}$ and $[\text{CoCl}_3(\text{H}_2\text{O})]^-$.

The results obtained lend no support to the views of Hill and Howell (*Phil. Mag.* 1924, 48, 833) that cobalt co-ordinated with six groups is red and with four groups blue. It is the electrical condition which is of most importance, not the co-ordination.

Prof. E. C. FRANKLIN.—*The Ammonia System of Compounds.*

Observing that ammonia resembles water in all its physical and chemical properties, and looking upon the familiar oxygen bases, acids and salts, the alcohols, ethers, aldehydes, ketones, &c., as derivatives of water and thereby constituting a water system of compounds, then it is reasonable to assume the existence of compounds analogously derived from ammonia. As a matter of fact, such an assumption has been experimentally justified. Using liquid ammonia as solvent in which to carry out the necessary reactions, it has been shown that the metallic amides and imides possess all the characteristic properties of bases, that the non-metallic amides and imides are acids the metallic derivatives of which are salts. Most organic compounds containing nitrogen may be interpreted as alcohols, ethers, aldehydes, acids, ketones, acetals, aldols, or as mixed compounds showing simultaneously the properties of two or more of these classes of compounds.

SECTION C.—GEOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 428.)

CAPE TOWN.

Tuesday, July 23.

Prof. A. YOUNG.—*The Geology of the Neighbourhood of Cape Town.*

Dr. F. DIXEY.—*The Geology of the Lower Shire-Zambezi Area.*

The Lower Shire-Zambezi area forms a relatively small salient between the better-known parts of Portuguese East Africa lying to the north and the south, and a study of its geology in relation to that of the larger territory has yielded interesting results.

Ancient sediments are represented amongst the crystalline rocks of the Port Herald Hills. The presence of sheared conglomerates and quartzites and of graphitic gneiss and magnetite-quartzites, associated with foliated hornblendic and other rocks, suggests a close relation to the crystalline schists of the southern part of Mozambique; while in the association of thick beds of white crystalline limestone with a wide range of metamorphosed sediments the rocks resemble the Turoka series and related rocks of Kenya and Tanganyika. Quartz-schists, quartz-felspar-schist and quartz-magnetite granulite showing varying degrees of metamorphism, together with crystalline limestone, are recorded also from amongst the oldest known rocks of northern Mozambique.

In addition to biotitic gneisses, pegmatite and basic dykes, the intrusives include large masses of nepheline-syenite resembling those from other parts of Nyasaland but hitherto unrecorded from Portuguese East Africa.

The Karroo has yielded results of especial interest. On palæontological and stratigraphical grounds it has been possible to recognise the Ecce, Lower Beaufort and Stormberg series. Beds containing *Rhexoxylon africanum* rest directly upon beds assigned to the Lower Beaufort, and accordingly the upper divisions of the Beaufort appear to be absent. The volcanic rocks include basalts with interbedded rhyolitic rocks, comparable with those of the Lebombo mountains in the southern part of Portuguese East Africa.

The Lupata series rests upon a deeply-eroded surface of the Karroo and older rocks. The lavas include an earlier rhyolitic series and a later unconformable alkaline series. The Upper Lupata Sandstones can be followed along the north bank of the Zambezi from the Lupata Gorge to the hills north of Mutarara, where the rhyolitic series reappears. The Lupata Sandstones, recognised also in the Lower Shire Valley, closely resemble the Dinosaur beds of North Nyasa, and in this and other respects recent work tends to confirm the view that the Lupata series dates back to the beginning of the Cretaceous.

The Tertiary is represented by intrusions of limburgite and olivine-nephelinite into the Mutarara sandstones.

Dr. G. SLATER.—*The Principles of Glacial Tectonics.*

The combined study of Arctic and Alpine glaciers on the one hand, and disturbed Pleistocene Drift deposits on the other, proves that obstruction to movement of a glacier results in the development of a definite tectonic structure. In Arctic glaciers, englacial material is incorporated in the structure, which, however, is largely destroyed during the formation of the marginal moraines, owing to the rapid rate of melting of the ice. On the other hand, in disturbed Pleistocene Drift deposits, lenticles or sheets of the local country rock, such as chalk or clay, have been frozen into the basal layers of the ice as englacial material. This material, after transportation, was subsequently moulded in tectonic forms which have been preserved as *pseudomorphs* after the melting of the interstitial ice. Classical examples of such deposits occur in the Norfolk cliffs of England, Møen and Lönstrup (Denmark), Rügen (Germany), and in the Mud Buttes of Alberta (Canada). The tectonic forms may be divided into two classes :—

I. *The Roche-moutonnée Type.*

The *roche-moutonnée* is associated with the forward movement of the ice. It may be carved out of the country-rock or may be moulded from the stranded englacial material of an overloaded ice-sheet. In modern glaciers, and in disturbed drift deposits, the material overlying the *roche-moutonnée* 'kernel' shows thrust-planes on the iceward-limb, tip-structure on the leeward-limb, and the development of a graceful asymmetrical or drumloid curve when seen in longitudinal section. Traced in the direction of movement of the ice a series of *roche-moutonnées* may be developed proving a switch-back mode of progression. In mountainous areas the 'kernel' is often the only part of the structure preserved.

The succeeding stage is shown by the accretion of transported material on the iceward-flank of the *roche-moutonnée*. This material is associated with pressure-gradients marked by a festoon of fan-shaped thrust-planes. The climax is shown by the development of a highly inclined plane which in cross-section forms a *sigmoid-curve*. The final result is the formation of a 'horst' of *drumlin-form*.

II. *The Stagnant-glacier Form.*

This type of tectonic structure is associated with the retreat of an ice-sheet. The disturbed beds have a uniform direction of dip and the structure is progressively developed backwards, i.e. in the opposite direction to that of movement of the ice. As in the *roche-moutonnée* type I, arrestation of movement leads to the formation of the sigmoid-curve which marks a zone of direct and concentrated pressure, relief from which is obtained as follows.

Movement against the plane of the sigmoid-curve results in upward flow, the curve being similar to the bent fingers of the hand. This flow-curve may be subsequently squeezed into an anticline having a pointed apex. Its form, therefore, is essentially different from an ordinary anticline. Moreover, it has no complementary syncline. Increased pressure from behind ultimately leads to relief being obtained by the formation of a thrust-plane, a process which may be repeated, at intervals, many times.

Imbricate or Schuppen-struktur.

The repetition of the same bed or series of beds associated with thrust-planes, leads to the development of imbricate, or *schuppen-struktur*. This zone, in turn, is associated with a series of domes and basins, the formation of which marks a decrease of pressure. The final stages are shown by the deposition of boulder-clay containing far-travelled erratics.

[See *Reports Brit. Assoc.* 1923-28 for abstracts of papers by the author on Glacial Tectonics.]

Prof. P. G. H. BOSWELL.—*The Action of Colloids in precipitating Fine-grained Sediments.*

Mr. W. N. EDWARDS.—*Triasso-Rhaetic Floras of the Southern Hemisphere.*

The close resemblance of the *Thinnfeldia* floras in different parts of Gondwanaland has recently been emphasised by Dr. A. L. Du Toit, and further resemblances are now brought forward, based on material in the British Museum (Natural History), e.g. the occurrence of the South African genus *Moltenia* in New Zealand. The southern *Thinnfeldia* floras are compared and analysed, and contrasted with Triasso-Rhaetic floras of the northern hemisphere.

AFTERNOON.

Excursion to Sea Point.

Wednesday, July 24.

Dr. A. V. KRIGE.—*The Geomorphology of South Africa.*

Mr. E. MCKENZIE TAYLOR.—*Base Exchange between Clay and Solutions of Sodium Salts and its Relation to the Formation of Coal and Petroleum.*

Bituminous coal and petroleum occur in unaltered sedimentary strata with similar biological, chemical and physical properties. The material forming the roofs of coal seams and the cap-rocks of oil-sands has been deposited under such conditions that it came in contact with solutions of sodium chloride forming a sodium clay. The sodium clay in contact with water breaks down, a solution of sodium hydroxide being formed. This solution of sodium hydroxide is a suitable medium for the decomposition of organic matter by bacteria. A further property of the sodium clay is that it is impermeable to water and gases. This ensures that the decomposition of organic matter situated beneath it is carried out in the absence of oxygen and results in the formation of residues containing little or no oxygen. It is suggested that coal has been formed by the bacterial decomposition of land plants under a sodium clay roof, and that petroleum has been formed by a similar decomposition of marine plants and animals. As coal and petroleum occur in strata of various geological ages and as the deposition of silt, under such conditions that it came in contact with solutions of salt, has been taking place from the earliest times, the suggested mode of formation of coal and petroleum accounts for the occurrence of these materials in rock-systems of various geological ages.

Prof. W. T. GORDON.—*Some Limestone Erratics from the Beardmore Glacier.*

Among the glacially transported fragments collected on the Scott Antarctic Expedition around Buckley Island—Beardmore Glacier—were several pieces of limestone which were handed to me for examination, on the chance that they might contain determinable fossil remains. While a few fossil forms have been obtained—and these of zonal value—the limestones are interesting from other points of view. Among them are two types of special significance, as they give evidence of the climatic conditions under which they were produced, namely, oolitic and conglomeratic limestones. The fossils also reflect on the physical conditions under which they lived.

As regards the age of these rocks we have satisfactory evidence, for the oolitic type contained a specimen of *Dokidocyathus*—a Lower Cambrian organism—while between the small pebbles of the limestone conglomerate a tuft of the alga *Epiphyton flabellatum* has been obtained. In the pebbles of the conglomerate rolled fragments of *Archæocyathus*, oolitic and algal limestones are seen, and *Thalamocyathus* and *Epiphyton flabellatum* have both been recorded in these pebbles. In other words the conglomerate was produced from the debris of oolitic, algal and archæocyathus-limestones of Cambrian age. Further, subsequent to the formation of the oolitic limestone, the latter had been dolomitised to a marked degree, the process beginning, as not infrequently happens, in the ooliths themselves.

The conglomerate contained fragments of partially and completely dolomitised oolite, so the process must have been proceeding during Cambrian times. Stated otherwise, in Cambrian times, on an area now close to the South Pole, conditions suited to the growth of algæ and archæocyathinæ must have supervened. Further, the conditions favoured the formation of oolitic limestones, permitted of the disruption of these limestones into conglomerates, and suited the dolomitisation of the limestones.

So far as arguments from other observations are available, such conditions could only exist concurrently in shallow and rather warm water. That is, the conditions were certainly not polar as we know them to-day. On the other hand, there is no *a priori* reason to assume that polar temperatures in Cambrian times were much different from those in corresponding latitudes to-day. These apparent contradictions may be reconciled on the assumption that the rocks of Cambrian age at present situated in South Polar regions were not accumulated in these latitudes, but had moved into that location since Cambrian times. The alternative hypothesis, that more genial climatic conditions prevailed over such latitudes in these early days, has no substantial foundation on observed facts. Of course, the notion of drifting continental masses is no new one; but the accumulation of observations from Arctic and Antarctic lands bearing on this problem may one day result in unravelling the history of the movement, and hence it appears worth while to draw attention to the most feasible explanation of the observations recorded above.

Dr. A. K. WELLS.—*The Significance of the Accessory Minerals of Igneous Rocks.*

AFTERNOON.

Excursion to Stellenbosch.

Thursday, July 25.

Excursion to Chapman's Peak and Cape Point.

In the evening the Section left for Laingsburg, arriving in the morning of the following day.

Friday, July 26.

The day was spent in studying the glacial and tectonic features of the Laingsburg district under the direction of Prof. A. Young. The Section left the same night for Kimberley.

Sunday, July 28.

Under the guidance of Dr. A. L. du Toit, members were conveyed in private motor-cars to Barkly West to examine the high-level diamondiferous gravels, which yielded large numbers of palæolithic implements.

Thence the party proceeded to Sydney on the Vaal, where the alluvial workings proved of great interest. In the afternoon a visit was paid to Nooitgedacht Farm where the famous glaciated pavements with coverings of Dwyka Tillite (Permo-Carboniferous age) were inspected. The occupiers, Mr. and Mrs. Dold, kindly provided refreshments.

Monday, July 29.

The Section visited the plant of the de Beers group of diamond mines, where the full operations for the recovery of precious stones were examined. Special facilities were afforded to the geologists for the acquisition of specimens from a very complete collection of rocks in the diamond pipes.

JOHANNESBURG.**Tuesday, July 30.**

Presidential Address by Sir ALBERT E. KITSON, C.M.G., C.B.E., on *The Utility of Geological Surveys to Colonies and Protectorates of the British Empire* (see page 64).

MR. E. D. MOUNTAIN.—*The Relations between Ray-Surfaces and Optic-Pictures.*

A method is described by which the sign of minerals may be determined in sections parallel to the optic axis or the optic axial plane. The method is applicable even to minerals possessing an optic axial angle approaching 90°. The determination is based on the comparison of the birefringence in certain directions in such sections.

Prof. R. B. YOUNG.—*The Geology on the Neighbourhood of Johannesburg.*

Mr. F. P. MENNELL.—*Suggestions on the Origin of Diamond Pipes.*

The general features of pipes and their characteristic inclusions were discussed; also the field relations of the granulite-eclogite group, to which many of the xenoliths belong, which appear to indicate that they are the result of the alteration of older rocks, including sediments, invaded by granite, rather than evidence of the character of the layer below the continental crust. The nature of the pipe-fillings would seem to show that they had their origin at comparatively limited depths, where explosive phenomena had full play and where, moreover, materials existed which would account for the explosions. Water is doubtless the usual agency in causing paroxysmal eruptions, but in this case carbonic acid seems demanded by the facts. The source of this may well be sought in the crystalline limestones so frequently found among the gneisses and schists of the region through which the pipes are distributed. The circumstances may be imagined as follows: During the earth movements at the close of the Cretaceous period, of which evidence is seen in the strata of Portuguese East Africa, the ancient rocks were no doubt subjected to the same gentle movement of elevation as the coastal sediments. This permitted the upward migration of probably basic magma at various points. These intrusions seldom reached the surface; in the exceptional cases when they did so it was in consequence of their penetrating and reacting with the ancient limestones, which led to their assuming an

ultra-basic character with accompanying production of large amounts of carbonic acid. This furnished the motive power for forcing a way through the superincumbent rocks and forming necks, sometimes filled only with the debris of those rocks, but in other cases followed by a welling up of the ultra-basic magma, frequently itself shattered by accompanying explosions. The associated earth movements being slight and soon reversed, the supply of molten material was small, and the first eruptions were only succeeded by the intrusion of a few stocks of melilite-picrite or its injection into the 'blue-ground' as small dykes. These last contain no diamonds, so it may well be surmised that the genesis of the diamond was the result of the crystallisation of carbonaceous material derived from the limestone, or of carbon due to the reduction of carbonic acid while the magma was still heavily charged with gas before the close of the explosive stage.

Prof. F. E. SUESS.—*The Structure of the Scottish Caledonids.*

July 31 to August 2.

The Section combined with the International Geological Congress in an excursion in the Witwatersrand.

Wednesday, July 31.

A study was made of the rock-groups cropping out in the area and their topographical expression, visits being made to the northerly-facing escarpment, to the Water-Tower Hill and to Klipriversberg.

Thursday, August 1.

A traverse of the syncline was made in motor-cars by way of Heidelberg to Blinkpoort. Here the glacial origin of certain Pre-cambrian Strata was confirmed by the discovery of a number of striated and facettled pebbles.

Friday, August 2.

The members were conveyed in small parties to a number of the Rand gold mines. The attention of some groups was confined to the methods of crushing the ore and extracting the metal, whilst others examined the underground workings.

Saturday, August 3.

Joint Discussion (Sections C, D, K) on *Gondwanaland*. (Prof. D. M. S. WATSON, F.R.S., Prof. A. C. SEWARD, F.R.S., Prof. G. A. F. MOLENGRAAF, Prof. O. ABEL, Dr. A. L. DU TOIT, etc.)

Prof. D. M. S. WATSON, F.R.S.—A land flora characterised by *Glossopteris* is widespread in South Africa, India, South America, Australia and other land masses in the southern hemisphere, in rocks of late Palæozoic age. This flora is accompanied by a reptilian fauna of which *Dicynodon* is the most characteristic form in South Africa and India, and both fauna and flora were unknown in the northern hemisphere until about 1900. It was therefore natural to believe that they had come into existence in a great southern continent, Gondwanaland, completely separated by sea from that which occupied the northern hemisphere.

Fossil vertebrates provide admirable material for testing the truth, or at least the necessity, of this hypothesis.

The only known Lower Carboniferous Amphibia occur in rocks of Coal Measure facies in Scotland. The descendants of these animals are found in similar forms in

the Coal Measures of Europe and North America, which must have been included in a single zoogeographical province. The known Tetrapod fauna is clearly that of the peculiar habitat presented by a coal-swamp. The direct continuation of this fauna is known in Stephanian rocks in France and Czecho-Slovakia and in the Rothliegendes. In the latter horizon it is accompanied by rare stragglers from the dry land in the persons of Pelycosaurian reptiles.

These forms are far more abundantly represented in the Artinskian rocks laid down under semi-arid conditions in Texas and New Mexico. Thus in Lower Permian time Europe and North America still formed one province, and two facies of its Tetrapod fauna are known.

No land vertebrates are known from any rocks in North America between the Artinskian and the Middle Trias. In Europe the copper-bearing sandstones of the Urals and the Kupferscheifer, which are earlier than the Zechstein, yield reptiles. The very incompletely known Ural fauna includes the amphibian *Zygosauros* closely allied to a Texan Artinskian animal and a series of reptiles which are morphologically intermediate between the Pelycosaur and the earliest South African Therapsids. The Kupferscheifer reptiles are of unknown affinities. The only Upper Permian reptiles known in the northern hemisphere are those from the Dvina and from Cutties Hillock, Elgin. These faunas contain Pareiasaurs and Dicynodonts, agreeing in evolutionary stage with those from the Cisticephalus zone of South Africa.

Thus it seems clear that the South African fauna of the Tapinocephalus zone, which is associated with *Glossopteris*, is a derivative of that from the Copper Sandstones of the Urals, which itself is a continuation of the dry land facies fauna of the Lower Permian of Europe and North America. There is no evidence to show that in Upper Permian times the Tetrapods of South Africa differed from those of the northern hemisphere, and some evidence that it did not.

Thus, from the standpoint of a student of Tetrapoda, there is no basis for a belief in a Gondwanaland.

Dr. A. L. DU TORR.—The existence of Gondwanaland is proved by a wealth of evidence, geological, palæoclimatical, palæontological and zoological. It remains an open question whether the several sections of the continental fragments were connected by narrow land-bridges, or by broader connections of continental width; or whether they have drifted apart as advocated under the well-known displacement hypothesis.

The boundaries of Gondwanaland naturally varied at particular geological epochs between the Devonian and the Jurassic, but, as seen on a globe, the southern continent would have occupied an extent fully the size of the land areas of the old world; under the Displacement hypothesis this would be cut down to about the land areas of the new world.

Life in Gondwanaland shows its first important divergence from contemporary life in the northern hemisphere just after the Lower Carboniferous, and was due to the onset of glacial conditions in the south. The cosmopolitan plant life suffered partial or complete extinction in the south, and was replaced by the *Glossopteris-Gangamopteris* flora; while in the northern hemisphere a break occurs between the floras of the Lower and Upper Carboniferous. In the Lower Permian of parts of Gondwanaland, however, relics of this northern flora occur. The *Gangamopteris-Glossopteris* flora is not absolutely confined to Gondwanaland: migration into Angaraland and Russia became possible in Upper Permian times. Early in the Triassic plant life in Gondwanaland dwindled to some half-dozen genera, although there is no sign that the environment was unsuitable to animal life. During the late Triassic immigration from Eurasia accounts for the strong resemblances between the land faunas of both the northern and southern continents. Floral evolution also was stimulated by this connection, in spite of a progressive tendency of the climate towards aridity. Now appears the *Thinnfeldia* flora in Chili, Argentina, South Africa, E. Australia, Tasmania and Tonkin. Many of the genera are of southern aspect, while several are apparently confined to Gondwanaland. During the Jurassic period exchange between the north and the south appears to have been freer.

Outstanding lithological parallelisms occur in the Rhaetic of South America and South Africa: each has an areally immense fine-grained sandstone formation, largely æolian, followed by vast outpourings of basalts and rhyolites, associated with widespread intrusions of dolerite, which are found also in Tasmania and Antarctica. Through the emission of these great volumes of magma the bonds connecting Gondwanaland were weakened and its fragmentation dates from about the beginning

of the Jurassic. The isolation of the fragments was complete by the end of the Cretaceous, and evolution proceeded independently in each portion. Particular biological affinities noted by zoologists and botanists may be explained by migration along temporary connections formed by folding in advance of the drifting crustal blocks.

This new concept of Gondwanaland revolutionises all extant ideas of palæobiology and seems to provide a golden key to the otherwise puzzling distribution of life in the southern hemisphere.

Dr. A. B. WALKOM.—The remarkable similarity in the development of the *Glossopteris* and *Thinnfeldia* floras, in Australia, South America and South Africa, proves land-connection between these continents in late Palæozoic and early Mesozoic times. The conception of 'Gondwanaland' as an extensive east-west continent on the southern side of an extended 'Tethys' sea is difficult of proof or disproof. W. D. Matthews has suggested the idea of the dispersal of faunas and floras along radial land-masses from an arctic continent. If there had been an Antarctic land-mass connected from time to time with South America, South Africa, Australia and New Zealand, faunas or floras originating in the south would be able to migrate into those land-masses with which there was connection at the time. Little or no mixture would be possible in the polar regions, but would be progressively more complete away from the polar continents. This suggestion is supported by admixture of northern plants with the *Glossopteris* flora in certain of the southern land-masses.

The *Glossopteris* flora originated in the south in Upper Carboniferous times and spread northwards, occurring in post-Permian rocks. The *Thinnfeldia* flora also originated in the south in Lower Triassic times, and spread northwards, becoming extinct at the end of the Triassic in the south, but persisting until the Jurassic in Germany where the species are, however, considerably different. It appears possible to account for most problems of distribution by migration from two polar continents along longitudinal continental masses, remnants of which are seen in the existing continents, and which were in temporary communication with the polar continents, but which were not always continuous from north to south.

Dr. R. BROOM, F.R.S.—The resemblances of the faunas and floras of South America and South Africa are infinitely greater than any resemblance they have to the Permian faunas and floras of the north. It is unnecessary to discuss whether the parts of Gondwanaland were originally in the positions they now occupy, or whether they have drifted apart from a central mass as on the Wegener hypothesis; the fact remains that there were southern lands which had very similar floras and faunas. The cases of transference of northern types to the south and vice versa are quite exceptional, and for long periods the northern and southern lands were completely separated. If we knew nothing of Gondwanaland we should have to invent it as a theory to explain the sudden appearance of new life-forms in the north. The incursion of higher types of life from the south appears to have given rise to the Mesozoic epoch in the north, and almost certainly it was another incursion from the south that ended the Mesozoic and ushered in the Tertiary. In America, in the basal Eocene, a large number of small mammalian types appear suddenly. They have no ancestors in the northern Cretaceous. Later, another wave of immigration resulted in the introduction of a large number of new and higher mammals in the Eocene: all these had originated in a great southern continent. Gondwanaland has been far more important in the world's history than any of the northern lands, and most of the great advances have originated in the south.

Prof. A. C. SEWARD, F.R.S.—The geographical distribution of *Glossopteris* cannot be explained without serious interference with the present relations in space of the several parts of Gondwanaland, a once continuous continental sheet that has become disrupted into isolated units. The earliest strata containing the *Glossopteris* flora are almost certainly Upper Carboniferous: the genus flourished within a few hundred miles of the pole, in the Falkland Islands, in South America, South Africa and Madagascar, in India and Afghanistan. The genus *Linguifolium*, from the lower Mesozoic rocks of New Zealand, is possibly generically identical with *Glossopteris*. By the Rhaetic *Glossopteris* had migrated to Tonkin, Southern Sweden and Eastern Greenland. The association of *Gangamopteris* and other Gondwanaland genera with northern Permian plants in the Kusnezki flora of Siberia resulted from the wandering of southern types across the Equator. Prof. Halle's memoir on the Shansi flora and the discovery of outliers of the northern Permo-Carboniferous flora in Sumatra and the Malay Peninsula show the wide distribution of the late Palæozoic forests, and

illustrate the importance of correlating palæobotanical data with geological data on the trend of mountain chains, which may have served as highways of migration.

In the Lower Carboniferous there were no well-defined botanical provinces, but the Upper Carboniferous flora of the northern hemisphere is different from that of the south, though the differences have been exaggerated, the northern flora being much richer and more varied than that of the south. The evolution of the *Glossop-teris* flora was in the main governed by climatic factors.

SECTION D.—ZOOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 428.)

CAPE TOWN.

Tuesday, July 23.

Joint Meeting with Section I (*q.v.*) on *Experimental Biology*.

Wednesday, July 24.

Prof. O. ABEL.—*Ideas on the Causes of Degeneration of Species.*

The struggle of life produces adaptations in the individual which may be advantageous or disadvantageous. It is difficult to recognise the latter among living forms, but the toe-reduction in the Ungulates described by Kowalesky and the carnassial teeth ('break-scissors') of the Hyænodontidæ and Oxyænidæ are fossil examples.

Palæontology clearly shows that the first step in the way of adaptation to a special environment or function is inherited and becomes a determining factor in further evolution. Such orthogenetic evolution of a disadvantageous adaptation would not be called Degeneration. In the ordinary course of variation or of development some individuals are 'defective' or 'degenerated.' As a rule they will not affect the adaptive or physiological value of the individuals of the next generation, because they will not reach maturity. An example is the stunted or famine form of the Stag Beetle (Roe Beetle) due to the lack of larval food in the Slavonian forests.

Degeneration in regard to *Morphological* characters manifests itself in the insufficiency of certain organs either in part or whole as compared with the sufficiency of the same organs in individuals of good health. In the *Physiological* sense the degenerated state of an individual manifests itself in the insufficiency of its reaction to the influences of its surroundings in comparison with the normal individual.

In famine or stunted forms the immediate cause is shortness of food. Opposite conditions may bring about the same result, as in the case of preserved game, where the survival and breeding of the feeble individuals gradually deteriorates the whole stock. The consequences of an easier struggle for life must always be the survival of more individuals and a wider variation, for the species which gains the optimum of life-surroundings seems to enter upon a flourishing period of evolution, which, however, is not of any phylogenetic value.

Unfortunately the increase of individuals in life-optimum conditions includes defective ones as well as those in good health, and natural selection is diminished at the same time. So the percentage of defective ones will increase until it becomes too great for the species as a whole. Natural Selection is therefore of enormous importance for the conservation of the species, and the history of a species, whose life-surroundings change from a hard struggle to a life-optimum, must, after a period of flourishing, end in extinction.

The foregoing theoretical reflections receive abundant support from the many thousand fossil bones of the Cave-bear (*Ursus spelæus*) in the Pleistocene deposits of the great Dragon Cave near to Mixnitz in Austria. There the ancestral form (*U. deningeri*) shows little variation, no healed injuries nor disease; while in the upper deposits the fossils show as wide a variation as the domestic dog, with severe fractures healed, co-ossification of the vertebræ, rickets in old specimens, serious

disease of the teeth, &c., showing that they must have been living in life-optimum conditions. In the uppermost layers there is a series of pigmy forms leading to extinction.

This example clearly demonstrates that the attainment of a life-optimum, after a more or less hard struggle for existence, is the greatest danger for a species' further evolution. It cannot be an isolated case, and probably those of the Dinosaurs, Ichthyosaurs and Plesiosaurs are other examples. A life-optimum will never produce any further evolution but only degeneration and, in consequence, extinction.

Prof. J. GRAHAM KERR, F.R.S.—*Spirula and the Morphology of the Siphonopoda.*

Mr. J. T. CUNNINGHAM.—*The Vascular Filaments on the Pelvic Limbs of Lepidosiren, their Function and Evolutionary Significance.*

In a publication on Fishes in 1912 Mr. Cunningham suggested that the water in the nest-burrow of *Lepidosiren* was probably deficient in oxygen, and that the function of the filaments on the pelvic limbs of the male when guarding the eggs was to provide oxygen not for itself but for the eggs and young, in other words not to absorb oxygen but to give out oxygen. Dr. G. S. Carter and Mr. L. C. Beadle in their recent expedition to the Paraguayan Chaco experimentally established the fact that the water of the swamps in which *Lepidosiren* lives is almost entirely de-oxygenated except at the actual surface, and independently drew the same conclusion that the pelvic filaments of the breeding male have the function of giving off oxygen for the respiration of the eggs and larvæ.

As it has not yet been possible to make experiments on the male *Lepidosiren* with regard to this point, Mr. Cunningham has made numerous experiments to ascertain whether the ordinary respiratory organs give off oxygen when fish or amphibia are placed in de-oxygenated water. The general result of these experiments is to show that oxygen is undoubtedly emitted, but it is difficult to distinguish what comes from the gills and what from the skin or other parts.

Assuming that reversal of oxygen-absorption takes place in the filaments, the case appears to be unique in the animal kingdom, though of course excretion of oxygen is known in the air-bladder of fishes. It is maintained that such a special adaptation cannot be rationally explained on the hypothesis of mutation undetermined by conditions. On the other hand, the question arises what kind of stimulus could give rise to such filaments in the individual. It is suggested that the pelvic limbs may have been used originally to move the eggs and larvæ about, and that not only the friction but the absorption of oxygen from the limbs may have been a stimulus to the growth of the vascular filaments. A similar stimulus may have acted in the case of the various larval respiratory organs in Amphibia, and in that of the allantois which is the embryonic respiratory organ in Birds, Reptiles, and Mammals. This is believed to be the first time that it has been suggested that the passage of oxygen through the tissues may act as a special stimulus to the growth of tissues and blood vessels, although it is in accordance with the general principle that functional activity causes growth which results in better adaptation to the function.

Miss A. E. MILLER.—*The Vertebral Column of Lepidosiren paradoxa.*

Mr. F. W. FITZSIMONS.—*Snake Venoms, their Uses and Possibilities.*

Afternoon.

Demonstration Session (Sections D, I), in Prof. L. T. HOGBEN'S Experimental Laboratory.

Mr. C. GORDON.—*The Permeability of Animal Tissues.*

Prof. L. T. HOGBEN.—*Conditioned Phenomena in Xenopus.*

ENID HOGBEN.—*The Respiratory Exchange in the Freshwater Crab.*

Dr. R. LAWRENCE.—*The Lung-books of the Scorpion.*

Mr. J. S. VAN DER LINGEN.—*Holothurian Hæmoglobin.*

Mr. L. MIRVISH.—*The Nervous Control of Colour Response in the Chameleon.*

Miss RUSSELL.—*Fertilisation Phenomena in the Cape Sea-urchin.*

Mr. D. SLOME.—*The Chromatic Response in Xenopus.*

Miss STARKE.—*Chromosomes and Cell-inclusions in Holopterna.*

Mr. A. ZOOND.—*The Octopus Heart.*

Dr. J. H. FERGUSON.—*Ultra-microscopic Examination of 'Surviving Blood.'*

Thursday, July 25.

Joint Discussion with Sections I (q.v.) and K on *The Nature of Life.*

Afternoon.

Excursion to Table Mountain.

Friday, July 26.

Dr. F. A. DIXEY.—*South African Lepidoptera in their relation to conditions of Climate and Vegetation.*

The lepidopterous fauna of South Africa is influenced in its character and distribution by the physical conditions of the subcontinent; chief among which are the configuration and elevation of the land, the action of oceanic currents, the direction of the winds and the incidence of the rainfall. These influences act upon the fauna largely through their effect on the vegetation; partly also by a more direct control.

The general land surface rises in a succession of plateaux from sea-level to an elevation of over 5,000 feet; the comparative poverty in natural vegetation of the uplands of the interior is accompanied by a corresponding scarcity of lepidopterous insects. The contrast between the west and east coastal regions is a marked one; the former, under the influence of the cold antarctic current, shows at corresponding latitudes a considerably lower average temperature than the eastern coast belt, which is washed by the warm water of the Mozambique current of the Indian Ocean. A further difference between west and east is afforded by the rainfall. Over a large portion of South-west Africa the rainfall is extremely scanty; at Walfisch Bay the annual average is under 1 inch. The amount generally increases as one goes eastward, being about 40 inches in Zululand. These differences of warmth and moisture have, naturally, a great effect on the vegetation and so on the wealth of insect life. The conditions on a large part of the eastern coast belt are subtropical, and from East London northwards the comparative abundance of lepidoptera, especially of butterflies, is very noticeable.

It is well known that in the western districts of the Cape Province the rain falls mostly in the winter; in other parts of South Africa the rainy season, if any, is in the summer months. This is due to the position in winter and summer respectively of anticyclonic centres, and the consequent course of the accompanying winds over sea or land before reaching a given area. Seasonal range in South Africa affects lepidoptera chiefly by alternation of wet and dry rather than of hot and cold conditions. The seasonal phases shown by many of the butterflies, especially *Pierinae* and some *Nymphalinae* are particularly well marked. They appear to be dependent partly on alternate abundance or scarcity of vegetation, partly on other causes, especially on the means of protection available under different seasonal conditions. The intimate relation between the vegetation and the lepidopterous fauna of South Africa is thus not merely a question of food; it is also concerned in many instances with various modes of ensuring the survival of a species.

Prof. TH. MORTENSEN.—*The Geographical Distribution of the Cidarids with special reference to South African and Antarctic Seas.*

A review of all the known recent forms of Cidarids, amounting to 150 (*circa*) species and varieties, shows a very marked overweight of the Indo-Pacific Cidarid-fauna over all other regions of the world.

The Malay Archipelago, and particularly the Moluccan part of it (the 'Amboinese' region of Döderlein) has by far the greatest number of species (48); next comes Japan with 26, the Indian Ocean with 21, and the Australian region with 18 species. In marked contrast herewith we have in the whole of the Atlantic, including the West Indies, only 16 species. During Mesozoic times Cidarids were extremely numerous in the seas occupying the place of what is now Middle and Southern Europe, about 600 species being known from these deposits, whereas there are now in the European seas in all only 4 species, including those known from the N.E. Atlantic Deep-sea. The explanation of this almost total disappearance of the former very rich fauna may be sought in the decline of temperature, from the tropical conditions of the Jurassic period to the arctic conditions of the Glacial Epoch. But the relative poverty of the tropical parts of the Atlantic cannot be explained in this way; it indicates that the Atlantic is of comparatively recent origin, so that there has not been time enough for the developing of a rich fauna. The theory of Wegener, of the Atlantic having been formed through the American continent drifting away from the Eurasian-African continent, or Ihering's Archelenis theory—the existence of a previous land-connection between Africa and S. America—may account for the fact of the relative poverty of the tropical Atlantic.

The Antarctic Sea has a rather rich fauna of Cidarids, 16 species, all belonging to a separate group showing several primitive features, this group being confined to the Antarctic, with the sole exception of a couple of deep-sea species found in the Pacific. It seems to indicate that the Antarctic Sea is a very old sea, in which this primitive group has found conditions for a rich development, being there free of competition of related forms. It seems to be a case analogous to that of the Marsupials of Australia.

In close relation to the Antarctic stands the Magellanic region, whereas New Zealand-Australia have no relation to the Antarctic as regards their Cidarids (and Echinoderms on the whole); only one of the New Zealand Cidarids shows some relation to the Cidarid characteristic of the Magellanic region, *Austrocidaris canaliculata*, which again belongs to the group peculiar to the Antarctic Sea. To this group also belongs a Cidarid found at Kerguelen and the adjacent islands. From S. African seas is known with certainty only one species of Cidarids, but at least two more appear to exist there; they are all decidedly of Indo-Pacific origin; with the Magellanic or the Antarctic region the S. African region has no nearer relation, judging from its Cidarid-fauna, and, indeed, from the whole of its Echinoderm-fauna.

Prof. C. G. S. DE VILLIERS.—*The Development of a Jonkershoek Species of Arthroleptella with some remarks on the Affinities of the Genus.*

In November 1928 several adults and representative stages of the life-history of *Arthroleptella* were procured in damp moss at Jonkershoek, Stellenbosch. The adults are small dark frogs inhabiting moss, and are probably widely distributed in the Western Province. They are preliminarily classed as Ranidae, but their development is quite different, since it is of the non-aquatic type also found in the Brevicipitid genera *Anhydrophryne* and *Breviceps*. The ova are rich in yolk, but telolecithaly has not called forth meroblasty. The albumen capsules are partially adherent and exceptionally large. The development of the gut from the yolk takes place in much the same way as in the Brevicipitids mentioned. The respiratory system is of great interest, since one pair of very small external gills only are developed and the internal gills are absent, although one branchial sac is present. The lungs cannot function till late, because the gut is not in communication with the oral cavity. The larval jaws and teeth, as well as the suckers, are absent. The pectoral girdle has aciferous epicoracoids in the metamorphosing froglets. The sternum of the adult has sternal sacs for the coracoids. A procoracoid is present, but there is no clavicle, as is sometimes stated. The scapula has a pronounced acromial process. The development of the skull has been traced, and the anatomy of the adult condition investigated microtomically, special attention being devoted to the os *en ceinture*, paraquadrate and quadrato-maxillary. The development and metamorphosis of the middle ear

and associated structures were elucidated. The branchio-visceral skeleton has an abbreviated development, but in the adult is quite Ranid. A spiraculum (atriopore) is never developed. Finally, the affinities of the genus are discussed.

Prof. J. E. DUERDEN.—*The Zoology of the Fleece of Sheep.*

An intensive study of the fleece of the merino has called for a comparison of the hairy covering of sheep, goats and mammals generally, and has revealed many facts of high zoological interest. Evolutionary series in different directions are disclosed, and many illustrations of recapitulation as well as of physiological adaptation. An interpretation of the nature of the winter pelage of animals is forthcoming, and numerous stages in the phenomenon of shedding.

South Africa is peculiarly favourable for a study of this character on account of the large variety of distinctive types of sheep and goats. The highly specialised woolled merino may be placed at one extreme, the black-head, primitively coated Persian at the other, the latter with its extraordinary fat-rump to be compared with the long, fat-tailed, indigenous Afrikaner; also the highly lustrous ringlets of the Angora goat are to be contrasted with the curly pipes of the Karakul.

Four morphologically distinctive types of fibres are concerned, known in wool terminology as kemp, wool, heterotypes and gare. These are represented in very different proportions in different types and in different ontogenetic stages. The rôle of the heterotypes, a fibre coarse and kempy above and woolly below, is elaborated, and furnishes a marked instance of convergent evolution.

Miss RUTH C. BAMBER (Mrs. BISBEE).—*Segregation.*

In the course of experiments carried out by Miss Herdman and myself on colour inheritance in cats, facts have come to light which do not seem to be consistent with the theory of the indivisibility of the gene.

Yellow and black in cats behave as a pair of allelomorphs. The heterozygote is tortoise-shell, but because of sex-linkage, it occurs normally only in the female. In a tortoise-shell female the black and yellow segregate. But all yellow cats examined by us have a few scattered black hairs, and this black does *not* segregate from the yellow. It seems as though the yellow is contaminated by black; but contamination would involve the splitting of the factor for black—and the gene is generally believed to be indivisible.

Further, in the course of our experiments, a yellow female appeared which had a few very small *spots* of black. Breeding experiments proved that this black did not segregate from the yellow. Again, the idea of contamination suggests itself.

Other explanations are possible, however, in both these cases, especially as the exact relationship between black and yellow is open to question. It is just possible that one underlies the other.

Later, however, we studied the inheritance of black and white in cats. Self white is dominant to black. But we find that most black cats, probably all, have a few white hairs. Here the relationship between the colours *is* known, and black, the recessive, should certainly be free from any trace of the dominant white, if the gene for white is indivisible.

Bateson pointed out that the members of any series of multiple allelomorphs differ from each other quantitatively only and argued that this was strong evidence for the fractionation of a factor. Goldschmidt's experiments on the Gipsy moth have led him to regard the members of a series of multiple allelomorphs as due to different quantities of the same factor and he, therefore, postulates the divisibility of the gene. Several other workers have made similar suggestions.

Our own observations, especially in regard to the *impurity of a recessive*, seem strongly to suggest fractionation of a factor.

The hypothesis of the indivisibility of the gene was built on the foundation of observed *clean* segregation of characters. Mendel's experiments did show such segregation. Other workers have looked for Mendelian proportions and, finding them, have emphasised Mendel's law—and with it the idea of clean segregation with the resulting purity of the gamete.

But this purity of the gamete seems, on closer investigation, to be relative rather than absolute. Recessive black in cats is *not* pure from the dominant white. Other cases are also known. In guinea pigs the recessive albino is *not* pure from the

dominant black. In man, the recessive albino is *not* pure from the dominant pigmented condition, and the recessive blue eye is apparently *not* pure from the dominant brown. In fox-gloves, the recessive white is *not*, as a rule, pure from the dominant pigmented condition. In all these cases, the recessive breeds true. How, then, can this trace of the dominant be explained? It seems inexplicable if the gene is really indivisible.

But the main importance of the observed impurity of the recessive lies in the fact that it shakes the very foundation on which the postulated indivisibility of the gene rests.

Had the recessive been found to be impure in early Mendelian experiments, the hypothesis of the *absolute* purity of the gamete could never have been put forward and the theory of the indivisibility of the gene would, therefore, never have been created to account for perfectly clean segregation.

Dr. R. BROOM, F.R.S.—*The Origin of the Mammalian Hand.*

A study of the manus and pes in the various groups of the Therapsida shows that the mammalian digital formula arose by the reduction and then loss of one phalanx in digit III and two in digit IV. In Anomodonts, Therocephalians, Dromasaurians and Bauriamorphs the formula is already 2, 3, 3, 3, 3, but in Gorgonopsians it is 2, 3, 4, 5, 3, with reduced phalanges in the third and fourth digits. In Cynodonts (*e.g.* *Thrinaxodon*) it is also 2, 3, 4, 5, 3, with the small phalanges still further reduced.

The curious arrangement of the Epiphyses in the metacarpals is explained by the fact that the first carpal is elongated and functions as a metacarpal.

Saturday, July 27.

Excursion to Sea Point and St. James.

JOHANNESBURG.

Wednesday, July 31.

Prof. H. B. FANTHAM.—*Some Remarks on Protozoa found in South African Soils.*

During the last ten years investigations have been made and reports published on the Protozoa found in 335 South African soils examined in water culture and in 114 waterlogged soils examined direct (see *S. Afr. Journ. Sci.*, vols. xviii-xxv, 1921-1928). Some Protozoa were found in all the soils examined, the number of species varying from 1 to 30. The total number of species of Protozoa found in all the soils examined was 117. The soils were collected from places in all Provinces of the Union—Basutoland, British Bechuanaland and Moçambique; waterlogged soils were mostly collected near Johannesburg. Cultivated and uncultivated soils, where possible, were examined from each locality. Conditions are very different from those of Great Britain, the soils being partially sterilised by the heat of the sun, and the wet and dry seasons are sharply defined. In the Transvaal, Orange Free State and Natal summer rains prevail, the Western Cape has winter rains, the Cape Midlands are intermediate. Soil cultures were examined daily, usually for three to four months.

It is very difficult to generalise on individual environmental effects. Darkness had little influence on development rates. Soils containing much humus yielded more kinds of Protozoa than sandy ones, the food supply being greater. Surface soils (0 inches to 6 inches deep) yielded more Protozoa than subsoils. Cultivated soils tended to contain more kinds of Protozoa than uncultivated ones, though exceptions occurred. Daily variations in numbers and the existence of a succession of dominant types of Protozoa have been found. Transvaal and Natal soils collected in the dry season have yielded fewer kinds and smaller numbers of Protozoa than those collected towards the end of the rainy season. Periodic collection and examination of a number of soils have shown the existence of seasonal variation in the composition and quantity of their protozoal fauna, the onset of warmer and moister conditions promoting protozoal activity, while great cold retarded multiplication.

Special study of soil collected monthly in Milner Park, Johannesburg, has shown that the number of species rose at the onset of spring but decreased with great heat or great cold. Few species of Rhizopoda and Mastigophora occurred during the cold weather, but Ciliata suffered less reduction in numbers. Rhizopoda were most numerous in samples collected in the summer months, and Mastigophora in September (spring) and December (summer) samples.

Observations on the Protozoa of waterlogged soil collected weekly for a year from the banks of Sans Souci dam, Johannesburg, show that the protozoal fauna varies in numbers with alteration of conditions, decrease in numbers occurring after sudden cold, great heat or great cold, increase in salinity and conditions causing stagnation of soil moisture. Increase in numbers coincided with access of clean, cold water. Mastigophora were dominant, their optimum activity occurring at the onset of spring. Relatively few species of Protozoa occurred in waterlogged soils.

Soils under irrigation for tobacco and sugar have been found to contain more species of Protozoa than the drier soils under cotton. Of soil samples from various sugar and banana lands, those with most moisture yielded the largest number of species of Protozoa in each case. The food supplies available for the Protozoa vary under these different conditions. The protozoal fauna of a number of soils from the Forest Experiment Station, Knysna, varied in high forests facing north and south; with presence or absence of tree ferns; and with eastern and southern aspects. Variations in illumination and moisture also caused considerable differences in protozoal fauna.

Storage of soil for three years did not entirely destroy its protozoal life, but diminished the numbers of Protozoa and altered the succession of dominant types. Veld-burning was destructive to cysts.

No general relationship appears to exist between the chemical reaction (*pH*) of the soil and the kinds and numbers of Protozoa found therein.

Species of Rhizopoda and Ciliata from South African soils often appear to be smaller races than those occurring as free-living organisms in water.

Prof. H. B. FANTHAM.—*Some Parasitic Protozoa found in South Africa.*

The present communication summarises some recent findings of parasitic Protozoa in South Africa, previous records having been published in the *South African Journal of Science*, vols. xv-xxv (1918-1928).

An interesting *Herpetomonas* has been found in the rectum and cloaca of two Cape cobras, *Naia flava*, out of nine examined. Morphologically it is quite distinct from *Herpetomonas homalosomatos* described by me from the steel snake, *Homalosoma latrrix*, in 1927. The bodies of the *Herpetomonas* of *Naia* are elongate oval, with both flagellar and aflagellar ends rounded. The single flagellum is longer than the body. Non-flagellate forms are rounded. Active multiplication by longitudinal binary fission occurred. The herpetomonad may have been derived from insects ingested by the snakes, the flagellates having adapted themselves to life in the ophidian gut.

Herpetomonas ficuum has been observed in Johannesburg in the latex of single leaves of *Ficus edulis* from two different sources. Leaves from twenty-eight other edible fig trees from different localities were negative. No marked pathological effects, other than very watery latex, were observed. Both flagellate and non-flagellate forms of *H. ficuum* were seen, the latter being much more numerous in the present (summer) specimens. Infections of the latex of *Araujia sericifera* by *Herpetomonas elmassiani* and of *Euphorbia striata* by *H. davidi* have been recently seen again in single plants.

Species of *Trichomastix* have been observed in the rectum and cloaca of *Bitis arietans* (puff adder), *Sepedon haemachates* (ringhals), *Pseudaspis cana* (mole snake), *Leptodira hotamboeia* (herald or red-lipped snake), *Trimerorhinus tritaenatus* (lineated schaaapsteker), *Psammophis sibilans* (hissing sand snake), *Boodon lineatus* (brown house snake), and *Dasyplettis scabra* (egg eater). Perhaps these flagellates are varieties of *Eutrichomastix serpentis*. *Varanus albigularis* (mountain leguaan) also harbours a *Trichomastix*. A species of *Trichomonas* has been found in the cloaca and rectum of the Cape cobra, mole snake, herald snake and boomslang (*Dispholidus typus*). Small numbers of *Giardia* have been seen in the rectum of a night adder and *Bodo* spp. in the Cape cobra, mole snake, egg eater, night adder and brown house snake. *Tricercomonas* has been found in the hind gut of several snakes. Multiple infections were fairly common.

Interesting flagellates have been observed in the midgut of the termite, *Hodotermes transvaalensis*, obtained in Johannesburg. These include species of Trichonympha, Spirotrichonympha, Dinenympha (Pyrsonympha), Leidyopsis, Devescovina, Oxymonas and Trichomonas. Only wood-eaters are infected. Further work on these organisms is in progress. Several species of Spirochaetes (Cristispira) and Treponemata have been found in the intestines of *Hodotermes transvaalensis*.

Among Sporozoa, a Hæmogregarine, *H. naiaæ*, perhaps a variety of *H. serpentium*, is recorded for the first time from one *Naia flava*. The cobra had no ectoparasites when examined.

Ciliates belonging to the genera Chilodon, Balantidium and Nyctotherus have been observed in the contents of the rectum and cloaca of one olive water snake, *Ablabophis rufulus*, the Chilodon being most numerous. One *Trimerorhinus tritæniatus* also contained a few such Ciliates.

Two new Protoopalínids have been found in *Rana fuscigula*, a host from which previously these Ciliates have not been recorded. One Protoopalina has an oval body and apparently has six chromosomes in its nuclei. It is proposed to name it *P. ovalis*. The second is striking, as it has a cercaria-like appearance with a narrow tail about half the length of the body and sharply demarcated therefrom. The number of chromosomes in each nucleus appears to be two or four. The name *P. appendiculata* is proposed for this new species. A small Protoopalina, apparently new, has been obtained from the hind gut of the tadpole of *Cacosternum bætteri*. The name *P. cacosterni* is proposed for it. This is the first record of a Protoopalina from *Cacosternum*.

Some of these organisms form interesting subjects for the parallel study of hosts and their parasites with reference to geographical distribution, though it is sometimes difficult to arrive at definite conclusions.

MR. B. SMIT.—*The Biological Control of the Blowflies of Sheep.*

DR. J. F. V. PHILLIPS.—*The Application of Ecological Research Methods to the Tsetse (Glossina spp.) Problem in Tanganyika Territory (formerly German East Africa): a Preliminary Account.*

The Tsetse problem, prior to 1928, had been approached from the medical, veterinary, entomological and protozoological aspects only. Important as have been the data derived from such studies, it nevertheless remains true that knowledge as to the behaviour of the Tsetse in Nature, and as to the factors governing such behaviour, has not only been meagre, but also disconnected and unorganised.

The objects of the present paper are to describe briefly the concept of the Tsetse research workers, Tanganyika Territory, and to outline the methodology they either are employing or intend employing in the early future.

During 1928 an investigation into the *Glossina morsitans* Westw. problem, in Kondoa district of Tanganyika Territory, was organised upon ecological lines. The concept inspiring the research may be defined thus:—

No definite advance toward the goal of control and combat of Tsetse will be consummated until basic, correlated data are available as regards (1) the nature of the behaviour of Tsetse under particular sets of conditions, (2) the mechanism of this behaviour, (3) the periodicity of this behaviour, (4) the causes responsible for the nature, mechanism, periodicity of Tsetse behaviour, (5) the particular habitat factors influencing the nature, mechanism, periodicity and causes of behaviour, (6) the application of information relating to the nature, mechanism, periodicity and causes of behaviour, to measures of control and combat.

The principal lines of research may be classified under the following heads:—

I. Reconnaissance.—Observations are made concerning (a) distribution and density of Tsetse, (b) distribution of vegetation communities and their major animal associates, (c) the correlation of Tsetse distribution and density with vegetation communities and their animal associates; II. Regular observations upon Tsetse density-activity, breeding and general behaviour in relation to season weather-conditions, vegetation, game and man; III. Tsetse autecology; IV. Tsetse synecology; V. The inter-relations of Tsetse, the biome and the physical environment; VI. The inter-relations of Tsetse and animals; VII. Alteration of the physical and biotic factors of the habitat so as to produce conditions unfavourable to Tsetse; VIII. Biological control.

Dr. ANNIE PORTER.—*Some South African Larval Flukes.*

Bilharziasis is a serious disease in South Africa, and for some years examinations of the larval Trematoda in freshwater molluscs with a view to determining the invertebrate hosts for human Schistosomes have been conducted. Other larval flukes have been observed and are more numerous than those of schistosomes. Most attention has been given to the parthenita and cercariæ occurring in molluscs proved to transmit human disease; the other non-schistosome hosts have received less attention. *Schistosoma hæmatobium*, the excitant of urinary bilharziasis in man, is transmitted chiefly by *Physopsis africana* and to a much less extent by *Physopsis globosa*, *Isidora tropica* and *Limnæa natalensis*. *Schistosoma mansoni*, the excitant of bilharzial dysentery, is much less common in the Union and is transmitted by *Planorbis pfeifferi*, *Physopsis africana* and *Isidora tropica*. *Schistosoma spindalis*, a rare human parasite, has *Planorbis pfeifferi* and *Isidora tropica* as molluscan hosts. *S. bovis*, not yet found with certainty in man, but causing epizootics among sheep, is harboured by *Physopsis africana*. An adult schistosome, agreeing morphologically with *Schistosomatium patholocopicum*, has been bred in the laboratory from cercariæ from *Limnæa natalensis*. Cases of human infestation with *Fasciola gigantica* and *F. hepatica* have occurred in South Africa and the cercariæ of *F. hepatica* occur in *Limnæa natalensis* and those of *F. hepatica* in *Isidora tropica*, *Limnæa natalensis* and *L. truncatula*, *Isidora tropica* being the most common transmitter. Cercariæ of *Paramphistomum calicophorum* and of *P. bovis* are found in *Isidora tropica*. Schistosomes and liver flukes are of much economic importance. Cercariæ of unknown adult schistosomes occur in very small numbers, and often as infections of one snail only, in all the transmitters of the human blood flukes. Further, both *Physopsis africana* and *Planorbis pfeifferi* harbour cercariæ that superficially resemble those of man, but are really unidentified Monostomes with forked tails. Some monostome cercariæ have been observed. A number of species of Echinostome larvæ have been obtained, mostly from *Limnæa natalensis* but some from *Physopsis* and *Planorbis*. One such was experimentally determined as *Echinostomum fulicæ*, parasitic in the redknobbed coot, the larvæ having been obtained from *Tomisia ventricosa* and *Isidora tropica*. The agamodistome stage of another echinostome is passed in the skin of *Xenopus laevis* and for purposes of reference has been termed *E. xenopi*. Xiphidiocercariæ are fairly numerous, particularly in *Physopsis africana*. Some interesting cystophorous cercariæ occur in *Planorbis pfeifferi*, and various Ancyliidæ contain monostome and cystophorous cercariæ.

The cercarial fauna of the Transvaal shows differences from that of Natal and the Cape, though some species are common to all. Human schistosomes have not been found hitherto in snails from Basutoland, the Orange Free State and the Western Cape. They are restricted to Natal, the Transvaal and the Eastern Cape Province. The same snails are responsible for bilharziasis in Rhodesia and Portuguese East Africa as in the Union.

It is not uncommon for the same species of cercaria to occur in several different genera of snails. Mixed infections have been observed in some instances. Experimental infestations of laboratory animals with human schistosome cercariæ often result in a great preponderance of male worms. While the hypothesis is suggestive, there is no real evidence for assuming that all the cercariæ from any one mollusc are of the same potential sex. Large and small strains of cercariæ are produced owing to differences in the development of the host, abundance or otherwise of the food supply, and amount of space in which development occurs.

The distribution of snails concerned with human disease depends on the suitability of the water for snail development, speed of the current, density of the human population, degree of pollution of the water and the presence or absence of enemies of molluscan life.

Dr. F. G. CAUSTON.—*Physopsis africana*, distinct from *Isidora* (*Bulinus*).

Dr. ANNIE PORTER.—*Some Remarks on the Hookworm Problem in South Africa.*

Hookworm disease in South Africa is due to both *Ancylostoma duodenale* and *Necator americanus*. It is localised and not endemic. It appears to be restricted to some sugar areas in Natal and to mining areas in the Transvaal, in each case being intimately

associated with the industrial labour supply. Hookworm appears to have been introduced into Natal by imported Indian labour. In the Transvaal, native labourers from Portuguese East Africa, where hookworm is endemic, form the chief source of mine labour and are the present source of infection. As new batches of these native labourers arrive weekly at the Witwatersrand gold mines, maintenance of infection is assured under ordinary mining conditions, since supervision of every individual native to ensure use of the proper latrines, and not promiscuous use of neighbouring unoccupied or disused workings, is impossible.

Natives rarely work a full year on a gold mine before returning to their kraals for a long period. In most cases, six to nine months' mine work is usual. They often lose their hookworms and other animal parasites after a short sojourn on the mines. Infected natives from Portuguese East Africa are rather of the carrier than of the suffering type, and rarely show obvious clinical symptoms. The presence of ova in stools frequently can only be detected with difficulty by concentration methods. Owing to soil contamination, hookworm has become established on a very small number of the deep-level gold mines on the Witwatersrand, and a relatively small number of white miners have contracted the disease. The use of large quantities of water for laying dust in order to prevent silicosis, together with the heat of deep mines, has produced conditions seemingly more favourable to hookworm than in the past. Incidence of infection varies from mine to mine, depending on working conditions, such as abundance of water and heat and newness or otherwise of sources of infection. Hookworm has recently been declared an industrial disease.

More native labour is needed on the mines. Mass treatment has been found impracticable on account of intercurrent disease conditions and concomitant helminthic and protozoal infections, that may cause fatal sequelæ. Mass examination of native stools is not practicable under present conditions, even by concentration methods such as are generally used. Examination of numerous mine soils by a modified Baermann method from all working levels has shown infestation with first, second and third stage larvæ of hookworms. Nematode larvæ from food-plants and larvæ brought in with water and from surface soil have to be differentiated in diagnosis from hookworm larvæ. Soils once contaminated may remain infected for long periods unless treated. Common salt, as advocated many years ago by the late Dr. G. Turner, has been used freely on the mines with good results, soils before treatment being heavily infested with eggs and larvæ but negative after application of salt. On one mine no white case has occurred as a result of frequent soil examinations, energetic salt treatment of positive sites and provision of new improved latrines in bad areas. Hookworm can thus be controlled in industrial areas by stool examination and treatment of cases, combined with the use of salt as a helminthic larvicide on soils. The danger of the disease becoming endemic in Union Native Territories, through soil contamination by infected natives returning from the mines, is possible but not very probable, since sterilisation of faecal matter by solar heat and hot sand occurs fairly quickly. The use of the bush near water for deposition of faecal matter is a far greater danger, as the damper conditions there favour hookworm development. Education of native and white man in hygienic principles is very necessary.

Various treatments for hookworm disease have been employed, the most favoured at present being carbon tetrachloride combined with oil of chenopodium.

A demonstration of the various stages of the life-history of hookworms, of concentration methods for detection of ova, and of isolation-culture methods for detecting larvæ in soils was given at the South African Institute for Medical Research.

Dr. C. J. VAN DER HORST.—*Metamerism in the Enteropneusta.*

Among the many and mostly hazardous hypotheses put forward by Willey in his work on the Enteropneusta there is one to which I should like to draw attention. Willey expresses his views in the following words: 'The gonads and gill-slits were primarily unlimited in number and coextensive in distribution, the gonads having a zonary disposition and the gill-slits occupying the interzonal depressions.' Spengel was opposed to this theory, as he was to all of Willey's theories and, in most cases, his objections were justifiable. This German author expresses his opinion concerning the metamerism of the Enteropneusta as follows: 'Solange wir uns nur an die nackten Thatsachen halten, können wir nur feststellen, dass das segmentweise Auftreten der Kiemen keinerlei Einfluss auf die übrige Organisation hat.' And later on he writes: 'Eine metamere Bildung der Gonaden zeigt sich in keiner Weise.'

The fact that the body of the Enteropneusta is divided up into three consecutive parts, the proboscis, the collar, and the trunk, each with an unpaired or paired coelomic cavity, is in itself not sufficient evidence for regarding them as segmented animals. There are, however, certain organs that may indicate an ancestral metamerism, or they may merely represent an incipient segmentation. Of these organs the gills are most important. They form a continuous and regular series in the frontal part of the trunk. The gills alone, however, are not sufficient proof of metamerism. Other organs, independent of the gills, should also show a metameric arrangement, corresponding to that of the gills. The liver saccules are also arranged in a more or less regular series, but they are of no value in this connection, as the liver region lies some considerable distance behind the gill region. The annular depressions and thickenings of the skin show a somewhat regular arrangement upon casual observation, but on closer examination it becomes evident that they too do not prove the existence of a possible metamerism. The only organs, other than the gills, that are of importance in this respect are the gonads.

Willey was unable to bring forward any fact in support of his theory, which was therefore only a supposition. Some years ago Meek described an Enteropneust, *Glossobalanus marginatus*, in which he found indications that the arrangement of the gonads coincided with that of the gills. I was fortunate enough to collect a species of *Dolichoglossus*, *D. caraibicus*, in which the gonads without exception alternate with the gill-slits. As there are over 50 gill-slits and the first gonad lies between the fourth and fifth gills, the genital and branchial region largely coincide in this species, which therefore definitely supports Willey's theory. The small *Dolichoglossus ottaensis* has only about ten gills. Nevertheless, in this species also an alternation of gills and gonads can be demonstrated and, furthermore, it gives an indication of the way in which the metameric arrangement of the gonads of other Enteropneusta may have been lost.

This regular alternation of two different organs proves that the Enteropneusta are related to the segmented animals. Moreover, the fact that an alteration of gonads and gills similar to that of these species of *Dolichoglossus* occurs in the young *Amphioxus* gives further support to Bateson's opinion that the Enteropneusta are closely related to the Chordata.

Thursday, August 1.

Mr. PAUL SELBY.—*South African Big Game in the Kruger National Park.*

Mr. D. R. R. BURT.—*A Case of Intersexuality in Bos indicus.*

Prof. J. VERSLUYS.—*On the Chalksacs in the Anura, with remarks on their probable Function.*

It is well known that in the frog we find on both sides of the backbone, closely adpressed to the spinal ganglia, chalk sacs filled with a milky substance, identical with the otoconia of the ear-labyrinth. They are diverticula of an enlarged unpaired Saccus endolymphaticus, also filled with otoconia, lying dorsally on the spinal cord. These curious chalksacs must be adapted to some special need of the frog.

Investigation of sixty-five species of Anura, belonging to thirty-five genera, showed that the chalksacs are often absent in Aglossa, Discoglossids and Bufonids, in most Hylids and Engystomatids. They are well developed in most Cystignathids and Ranids.

We found a correlation between the habits of the animal and the chalksacs. These are absent in all purely aquatic Anura, also absent in nearly all tree-living species, whether Hylids, Ranids or Cystignathids. *Hyla aurea* has chalksacs, but it never climbs trees. The Cystignathid *Hylodes Schmidtii* has small chalksacs, but it also climbs trees no more. This points to loss of chalksacs in such Anura that took to climbing on trees. Only in one tree-living Hylid, *Nototrema*, we found well-developed chalksacs.

Of ground-living Anura, the Bufonids and Engystomatids have none. These forms have very limited jumping power. When forced to take long jumps, they generally fall on one side or overturn. The only Engystomatid with chalksacs, *Rhinoderma*, has long legs and jumps remarkably well. All the Anura that have

well developed chalksacs have this in common, that *they jump well, coming down in a normal position, enabling them to make quick successive jumps as a mode of rapid progress.* So the typical *Rana*'s, some *Cystynathids*, and the *Engystomatid Rhinoderma*.

It is very rare that chalksacs are present in a form that is not *known* to jump well. So *Ceratophrys*, a toad-like *Cystignathid*, but it may be a good jumper after all. *Nototrema*, a tree-frog with well-developed chalksacs, seems an exception to the given correlation; but its hind legs are stronger and not so lengthened for climbing on trees as in typical *Hylids* and it may be a good jumper when moving on the ground.

The observation that well-developed chalksacs on the spinal ganglia are correlated with special jumping power, points to the conclusion that they are connected with the equilibrium in jumping, giving the animal a warning, when it is losing its equilibrium, perhaps automatically inducing such movements of the muscles of trunk and legs, that equilibrium is regained, working in a quicker way than the ear-labyrinth.

The chalksacs could then only work by the weight of the otoconia influencing in some way the spinal ganglia. This would explain why the chalksacs are so closely connected with these ganglia, including the hindermost of the sacral plexus. It is obvious that in those *Anura* that jump very far, a special demand is made on the sense of equilibrium.

The enlarged *Saccus endolymphaticus*, filled with otoconia lying dorsal to the spinal cord, must also be connected with some special need of *Anura*, as no other Vertebrate possesses the like. It is absent in some *Anura*, that have given up jumping (*Aglossa*, *Discoglossus*, *Pelobates*, *Phyllomedusa*). Now the only really aberrant character of a primitive *Anura* was development of jumping power. This could have caused the formation of an accessory static mechanism by enlargement of the *Saccus endolymphaticus*, but I can only suggest this.

What I have brought forward is a working hypothesis only for the physiologist. But it may show a way for settling the function of the *Saccus endolymphaticus* and of the chalksacs. This communication is made also on behalf of Dr. Pilz, who had a large share in the work reported on.

MR. J. H. POWER.—*Recent Advances in our Knowledge of South African Amphibia.*

The number of described species and sub-species has been considerably added to since the last visit of the British Association for the Advancement of Science.

Research work in the field has been prosecuted much more systematically, with gratifying results.

A feature of outstanding interest is that a number of species seem to be confined to the Cape Peninsula. A varied frog fauna numerous in species flourishes along the Indian Ocean coast belt, whereas the Western or Atlantic coast belt, because of the prevailing desert conditions, has only a few species.

The highly specialised larvæ of certain South African genera and species are described, and remarkable instances given where the study of the larvæ has thrown light on the affinities of certain South African genera with Asiatic, Australian and American forms. On the whole, the information gained regarding the larvæ of the South African Amphibia tends to support the thesis that all forms of a natural group will tend to exhibit the same larval specialisations.

Friday, August 2.

DR. G. S. CARTER.—*Bionomics of Swamps and Marshes, especially those of the Tropics.*

MISS P. M. JENKIN.—*A Preliminary Survey of Certain Tropical Lakes in Kenya.*

I reached Kenya on April 12, 1929, and stayed a night in Mombasa to clear my apparatus through the Customs and to send it up-country on the next day's passenger train. I reached Nairobi on April 14 and purchased a second-hand car; this was essential to the expedition as my bases were to be at least ten miles from the lakes, and it carried me some 2,000 miles before being sold again on my departure.

I reached my first base, the camp of the East African Archaeological Expedition, on April 16 to work Lake Nakuru and Lake Elmenteita. On June 5 I moved forty miles south to a friend's farm to work Lake Naivasha until July 11, when I had to leave to catch the boat again on July 13.

I was also able to visit Lake Baringo on May 2 and a small Crater Lake on June 16.

On Lake Nakuru (9' 3" max. depth) four days were spent in taking water samples, reading temperatures and hydrogen-ion concentrations and collecting with the townet and grab. Three other days were spent in making photosynthesis experiments on the depth of penetration of light, using the filamentous green Algæ that were abundant in the lake. This lake was highly alkaline, due, it is believed, to the presence of sodium carbonate.

On Lake Elmenteita (6' 2" max. depth) three days' collecting showed the lake to be of the same type as Lake Nakuru, although slightly less alkaline (.22N as against .27N) and supporting apparently two species of planktonic Rotifers instead of one.

On Lake Naivasha (60' max. depth) nine days were spent in collecting at different deep-water stations. The water proved to be comparatively fresh (.004N) and good quantitative hauls of planktonic Copepods and Ostracods were obtained from a number of depths. Four days were also spent here in attempting, rather unsuccessfully, to make photosynthesis experiments with *Myriophyllum* sp. A further three days were spent in collecting among the inshore weeds, where definite zoning was apparent, and rich catches of Cladocera, Ostracoda, Insecta, Hirudinea and Polyzoa were obtained. Mollusca were present here though absent from all the other lakes examined. Fish were also present in Lake Naivasha as well as in Lake Baringo, the latter also having quite abundant planktonic Entomostraca, but no weed-inhabiting fauna, since the alkaline content (.01N) was apparently high enough to inhibit the growth of macroscopic plants.

The variety and abundance of the fauna appeared to vary in inverse proportion to the quantity of alkali in solution in the waters of these lakes.

The shallowness of the soda-lakes prevented the establishment of any very definite layering, except in the case of the oxygen content; this was measurably lower in the layers immediately overlying the decomposing mud on the floor and shores of these lakes than in the layers nearer the surface.

I was promised the use of a large motor-boat on Lake Naivasha, but unforeseen circumstances prevented its being available till my last day, when some good catches were obtained from it. My scheme for taking samples at night had therefore to be given up, as it was not considered wise to attempt it in the small rowing boat used by day.

Twelve days were spent in packing, unpacking and moving from one base to another.

Most of the remaining fifty-four days were spent in fixing and preserving the specimens and carrying out analyses, on about forty water samples, for alkali-reserve, dissolved oxygen and, in many cases also, for silicates, phosphates, chlorides and magnesium, the different lakes showing a wide range of variation.

The specimens collected, including a number of Mammalian parasites, some insects and a few snakes and lizards, &c., have all been sent to the British Museum for further investigation.

Dr. L. B. RIPLEY and Mr. G. A. HEPBURN.—*Olfactory and Visual Reactions of the Natal Fruit-Fly (*Pterandrus rosa*) as applied to Control.*

Presidential Address by Prof. D. M. S. WATSON, F.R.S., on *Adaptation*.
(See page 88.)

Dr. C. M. YONGE.—*The Great Barrier Reef Expedition.*

Afternoon.

Visit to the Institute of Medical Research (by the kind invitation of the Director).

Saturday, August 3.

Joint Discussion with Sections C (*q.v.*) and K on *Gondwanaland*.

Afternoon.

Visit to the Rietfontein Grass Pan.

Sunday, August 4.

Excursion to the Government Veterinary Research Laboratories, Onderstepoort (by the kind invitation of the Director).

EXHIBITS.

Mr. D. R. R. BURT.—*Rubber Latex as an Injection Mass.*

Dr. LEONARD GILL and the Staff of the South African Museum.—*Exhibits of South African Fauna.*

Miss D. J. JACKSON.—*Wing Dimorphism of Sitona Hispidula and the Production of Flightless Macropterous Forms through Abnormal Development of the Muscles of Flight.*

Dr. ANNIE PORTER.—*The Hookworm Problem.* (In the Institute for Medical Research.)

Mr. J. H. POWER.—*South African Amphibia.*

Miss CLARA WEINBRENN.—*Variation in the Skulls of Cercopithecus pygerythrus.*

Prof. H. B. FANTHAM.—*Some South African Animal Parasites, as illustrated by Examples from the Protozoa, Helminthes and Insecta.*

SECTION E.—GEOGRAPHY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 428.)

CAPE TOWN.**Tuesday, July 23.**

Joint Meeting with Geophysical Department of Section A for papers on Geodesy :—

Presidential Address by Brigadier E. M. Jack, C.B., C.M.G., D.S.O., on *National Surveys*. (See p. 100.)

Dr. VAN DER STERR.—*Progress of the Trigonometrical Survey in South Africa since 1905.*

Mr. G. T. McCaw.—*The African Arc of Meridian.*

At the last meeting of the British Association in South Africa Sir David Gill gave an account of the initiation and progress of the Geodetic Survey of the sub-continent. Some considerable time before 1905 he had not only visualised the measurement of an Arc of Meridian through the whole of Africa, and even beyond it, but had succeeded in ensuring its commencement as an extension of the Geodetic Survey of the Union. Since the British Association, during this year, has brought to the notice of the Home Government the desirability of completing this Arc, it is not unfitting that it should be discussed at the coming South African meeting.

After the Geodetic Survey of Southern Rhodesia had been completed by Mr. A. Simms, the connection with the Transvaal was made by Capt. (now Major-General) H. W. Gordon, R.E. Almost simultaneously Dr. Rubin carried the Arc northwards through North-eastern Rhodesia; but by reason of various difficulties it did not reach the terminal on Lake Tanganyika projected by Mr. Cecil Rhodes—one of the last decisions of that great administrator. Thus in 1906 the survey stopped short of 10° S., whence to Uganda there is a gap of $9\frac{1}{2}^{\circ}$ of latitude.

Following on a resolution of the old International Geodetic Association, German geodesists proposed to carry the Arc through Tanganyika territory; but the heavy estimate put before the German Colonial Authorities by Helmert was considered as exacting too great a burden on the then meagre resources of the colony.

In 1905 a dispute had arisen on the Uganda-Congo frontier, involving 6,000 square miles of territory. When the work of the Commission sent forthwith to map this large area was approaching completion, Sir D. Gill asked the Colonial Office to carry the Arc through the belt mapped by the Boundary Commission, part of the expense to be borne by the scientific societies. Thus 2° of latitude were measured in Uganda under the direction of the present chairman of Section E, £1,600 having been contributed by the British Association, the Royal Society and the Royal Geographical and Astronomical Societies.

The longest portion of the Arc still to be measured is that through the Sudan, with a small part in Uganda. From the southern end of Lake Albert to Wady Halfa this stretch extends to about 21° in all. It is likely to involve some special difficulties, for the Sudd region of the Nile lies on the way, and this area will have to be circumvented.

From Luxor northwards to Cairo the measurement, initiated by Col. (now Sir Henry) Lyons, F.R.S., was completed by the survey of Egypt.

These brief notes give the outline, history and present position of the Arc of the Thirtieth Meridian in Africa. Where the work has been completed it already forms the ruling framework of all local surveys. In the Sudan, particularly, the need for such a framework is now clamant, and in Tanganyika the sooner it can be undertaken the less will be the expense to the mandated territory, where the surveys hitherto executed are generally isolated and of very variable quality. Uganda is pursuing a policy of active development of its control surveys, but in Northern Rhodesia progress in this direction has been slight.

Though there is this long reach between Rhodesia and Uganda, there is nevertheless a chain of secondary triangulation connecting the two portions of the Arc. This chain, in part Belgian, has given a very satisfactory close in longitude; in latitude and azimuth the discordances are rather large. They have been adjusted in provisional fashion by the joint co-operation of Commandant Maury, of the Belgian Ministry of the Colonies and the Geographical Section of the General Staff. This question of adjustment has already assumed importance, particularly in the connection between the Transvaal and Rhodesia. This and other adjustments will be discussed in the paper, to which the present abstract may serve as an introduction.

Mr. W. WHITTINGDALE.—*Map-making in South Africa.*

Mr. H. G. FOURCADE.—*A New Method of Aerial Surveying.*

In two previous papers on the same subject the use of inclined plates was alone considered, because it seemed that such plates being better conditioned, there was no need to develop the particular case of plates exposed in an approximately horizontal position. A number of other considerations which are discussed make it, however, desirable to do so.

In the present paper the method is therefore applied to the simpler case of horizontal plates, and this leads in turn to some further simplifications in the treatment of inclined plates. Comparison of the respective advantages of horizontal and inclined plates is then made. Lateral extension from aerial bases, and several other minor points are also dealt with.

Wednesday, July 24.

Prof. E. WALKER.—*The Effect of Relief of South Africa on Settlement.*

Main features of relief are (a) unbroken coastline, (b) three more or less definite terraces rising from coast to east-central plateau behind escarpment of Drakensberg and (c) highest edge of this plateau (High Veld) facing south-east.

Height inland gives level average of yearly temperature in spite of difference of latitude; hence, possibility of speedy settlement by same kind of people all over it and even further north where ground is high enough, e.g., S. Rhodesia.

Rivers, plunging down from plateau and terraces, are useless as means of communication. This and absence of sea inlets cut off bulk of Union from contact with the sea. Deep river beds do not help the irrigator.

Summer clouds from south-east give rain to most of Southern Africa. Heavy rainfall in Portuguese East Africa and sub-tropical coast of Zululand-Natal. Malarious back blocks of P.E.A. delayed development there till the coming of Transvaal and Rhodesian gold mines and railways in the 'nineties. Twenty-five inches of rain in Cape Native Territories, Basutoland and eastern Free State and eastern Transvaal. Kaffir wars (1779-1878) and Free State-Basuto wars (1858-68) fought out along this line; wars for land and not for cattle. Fifteen inches' fall as far west as line running outside Free State and eastern Bechuanaland; the limit which the late Republics tried to reach. Missionaries' road and railway to Central Africa run near this line, because, for political reasons, they could not go along 'the line of life' through Transvaal. Kalahari and South-West Africa get very little from south-east clouds. West Coast also misses winter rains brought by north-west winds, and remained unoccupied till diamond discoveries and railways of twentieth century.

North-west rains catch south-west corner round Cape Town. European penetration began in these 'Mediterranean' lands in 1652. Formation of agricultural colony by 1700 up to first range of mountains thirty miles inland. Sandy Cape Flats made Peninsula an island; helped division of interest between maritime Cape Peninsula and corn and wine farmers, and development of cattle-farming. Trek Boers became stereotyped in passing round or through barren and high Karroos. By 1770 these frontiersmen were out on to better lands near Fish River. Karroos a barrier between Western and Eastern Cape provinces.

Two lines of advance in early nineteenth century (a) Continuation of eastward thrust in face of Bantu resistance. Failure of territorial segregation; no natural frontiers. By 1865 line between Colony and Native Territories fixed at Kei River. (b) Trek Boers swerved north-eastward; on to the High Veld before 1795; Great Trek crossed Orange River 1835-40. High Veld republics: Free State south of Vaal, Potchefstroom, the nucleus of the Transvaal, beyond it. Resistance of tribes helped in the west by lack of surface water, by fever and mountains in the north (Bush Veld), and by mountains in Basutoland to south-east.

Dominant area of Natal in sub-tropical coast belt. Sugar and Indian labourers.

Industrial revolution began suddenly in 'seventies. Diamonds and then gold mines and railways invaded Trekkers' refuge on High Veld. Gold in ancient rocks, coal in overlying shales and sandstones. Rhodes's Pioneers cut Trekkers off from high ground beyond Limpopo. To-day, Trekkers are trekking into the towns.

Prof. P. SERTON.—*Economic Development under 'Desert' Conditions in the Western Karroo.*

1. A considerable area in the Western Karroo has an average annual rainfall of less than 5 inches. The driest part of the Kalahari (in so far as can be judged from the available data) has between 6 and 10 inches. Compare these figures with those for other dry regions on earth. Conclusion: the Western Karroo, though more favoured than e.g. the worst parts of the Sahara, gets as little rain as many regions which are generally considered to be deserts.

2. Rainfall figures in relation to temperature. Climatic formulas of Köppen and Lang-Hirth. Scarcity of available temperature-records in South Africa. Esti-

mates by means of interpolation. Area in the Western Karroo, which must be called desert according to Köppen, or classified under the driest type of arid climate according to Hirth. Comparison with other dry regions.

3. Distribution of population in the Western Karroo. Small direct influence of rainfall. Comparison of density-figures with those for the Kalahari, the American Plateau States, and the dry regions of Australia.

4. Economic conditions and the human and natural factors by which they are determined. No mining; no industries; types of farming. Geology. Relief. Nature of Vegetation. River-system. Underground water. Historical influences. Character of population. Transport. Markets.

5. Conclusions. Reasons why the Western Karroo cannot be called a desert in the geographical sense of the word.

Mr. R. J. VAN REENEN.—*Utilisation of Available Water Supplies in South Africa.*

This paper treats mainly of conditions within the boundaries of the Union of South Africa and the mandated territory of South-West Africa.

The sub-continent consists of a moderately humid coastal belt, surrounding a high-lying plateau on which the rainfall, usually considerably smaller than on the marginal area, diminishes from east to west.

The purposes for which water is used fall broadly into the following classes:—

- (i) Domestic.
- (ii) Agricultural and stock farming.
- (iii) Fishing.
- (iv) Power producing.
- (v) Industrial, and
- (vi) Transport.

While all these uses are interesting and of importance to society, the use of water in maintaining life, that is in agriculture and stock farming, is of prime importance and of the most interest to the Association.

The country is divided into winter- and summer-rainfall zones. The raising of crops in the former is possible on a much smaller annual rainfall than in the latter. Where the rainfall is insufficient agriculture is possible only under irrigation. The ultimate extent of irrigation in South Africa is definitely limited both by the rainfall and the low percentage run-off. Owing to the nature of the incidence of the rainfall large storage works are necessary. Owing to the nature of the country such storage works are costly.

The water reaching the rivers and water-courses is but a small proportion (about $6\frac{1}{2}$ per cent.) of the total water falling on the country in the form of rain. The efficient utilisation of the remainder ($93\frac{1}{2}$ per cent.) is of far greater economical importance to the country. To render the use of that water more beneficial, improvement in the methods of dryland farming and, what is perhaps economically even more important, improvement in the practice of grazing, is needed.

The problem of increasing the pastoral products of the country has up to the present been almost entirely a problem of jackal extermination, and the most successful weapons yet devised for the combating of the jackal are fencing and bore-holes.

Underground water for drinking purposes can be obtained by means of wells or relatively shallow bore-holes, without great difficulty. But little artesian water has been developed.

Dew ponds do not provide a feasible method of supplying water for the greater part of the sub-continent. In South-West Africa underground dykes or 'grundschwelle' are employed with great success in obtaining water from the beds of intermittent streams.

Legal and financial phases of the matter are beyond the scope of this paper.

Thursday, July 25.

Dr. MARION NEWBIGIN.—*The Mediterranean Climatic Type: its World Distribution and the Human Response.*

The paper includes a comparative survey of the five world regions in which the Mediterranean type of climate occurs in typical form. It is pointed out that of these

regions three, the Mediterranean Lands proper, the Central Valley of California with southern California, and the Central Valley of Chile, show a number of features in common. In all the contrast with contiguous areas is marked as regards possible modes of life, this being associated with the presence of definite relief features which form climatic divides. In all three, therefore, the areas of Mediterranean climate show a high individuality and distinctiveness. On the other hand, the two remaining areas, the south-western corner of South Africa and those parts of south-western and southern Australia in which the climatic type occurs, lack this distinctiveness. It is indeed characteristic of sub-tropical Australia that 'Mediterranean' crops tend to be grown largely outside the range of the Mediterranean climate. From the standpoint of human geography, therefore, as opposed to the climatological one, the recognition of a Mediterranean region there seems of little value. The paper then proceeds to study the course of development in the world regions of Mediterranean climate, with a view to examining the common assumption that the type is one peculiarly suited to human endeavour, and that the lands in which it occurs are areas of much natural wealth, capable of supporting dense populations of cultivators. It is pointed out that even in California, where recent developments have been most spectacular, there is no great evidence to justify this assumption.

Prof. O. H. T. RISHBETH.—*Some Problems of the Livestock Industry in Australia.*

The significance of the livestock industry at the present time due primarily to the interrelation, and progressive interaction, of two major regional phenomena: increasing pressure of food demand from the human 'high-pressure' areas of the northern hemisphere (notably U.S.A. and Great Britain) and the intensifying national development of three major 'peninsular' areas of the southern hemisphere (Argentina, Union of South Africa, Australia). The issues involved on both sides are far-reaching, and of considerable importance also for the internal economy of the British Empire. The three southern areas, while possessing many common features, exhibit significant geographical variation. The livestock industry of Australia of interest to the Union (*cf.* recent delegations and tours of investigation), whose 'physical conditions . . . permanently impose upon it farming predominantly of a pastoral character,' and whose competitive position—as regards both production and marketing—is necessarily of increasing moment. The problems of the industry are geographical in so far as they are largely rooted in geographical circumstances, and in that possible solutions must conform to geographical laws.

Dairying in Australia, while well-established over the greater part of its probable ultimate area of extension, shows certain features of transition, growth and intensification. Two here selected are: (a) *Regional adaptation and differentiation*: this, though proceeding, is as yet imperfectly achieved. In the four main types of area occupied—those of (i) winter, (ii) summer, (iii) 'uniform,' (iv) low rainfall—recent progress most marked in (ii). Analysis reveals the wider significance of this development and its bearing upon cognate economic trends in other countries, including the Union. Yet development in (iv) may possess greater ultimate importance in Australia; (b) *Stabilisation*: Instability, though partly 'derivative' and capable of alleviation by purely economic means, primarily a geographical problem. The variables, once accurately known, provide within the given geographical limits equations of which the solution is proceeding.

Sheep.—One problem of major geographical and economic significance selected, viz., regional differentiation of type. Natural differentiation (on basis mainly of climate and physiography) already well marked, but tendency for (a) inherited characters, (b) market requirements to restrict variation. Selective development and intensification of existing variations may provide greater economic flexibility and stability and closer adaptation to specialised markets.

(*Beef*) *Cattle*.—The urgency of world's beef supply problem hardly needs emphasis (*c.f.* Sir W. S. Haldane's recent contributions to *The Times*). The present problem in Australia due to (i) normal economic evolution, (ii) inadequate appreciation of, or adaptation to, the special geographical situation. Analysis of the factors operative under (i) and (ii) facilitates judgment as regards the present, and an estimate of the future, position.

Problems common to more than one branch of the industry.—A summary survey of problems involved in primary land development, stock maintenance and manage-

ment and labour supply leads to consideration of significance of conditions of land-tenure and land-subdivision. The problem seen to rest upon (i) basic physical conditions, (ii) basic social concepts and ideals, (iii) stage of economic and political growth. Some recent statements and criticisms reviewed (*e.g.* Report of Queensland Land Administration Board; British Economic Mission) and the bearing of present tendencies in Australia estimated.

Friday, July 26.

Prof. H. J. FLEURE.—*European Cities.*

Cultivation of wheat and barley, originating in S.W. Asia and N.E. Africa, was attended by many inventions, making life more settled, so that the village grew and a considerable development of religious ideas and of material exchanges followed, and centres of expression of these activities became cities. These ideas spread piecemeal to Europe both via the Mediterranean and through the lands around the Black Sea to the loess-regions of Central Europe. The latter spread appears to have been more fractional, and the village remained the typical form of social expression until the Middle Ages were approaching. In the former case the city, with its attendant religious and commercial organisation, appeared probably before 2500 B.C., as at Hissarlik and Knossos. There is thus a difference of some 3,000 years in the date of the birth of cities in the two regions.

The Europe of the City Civilisation, *i.e.* the Mediterranean Basin, falls naturally into eastern and western regions, the city being of much later date (Rome, traditionally, 753 B.C.) in the western one.

Roman organisation of communications spread the idea of the Roman quadrate city north-west and north of the Alps, but sometimes the city grew from a village, apparently just a heap of houses (*Haufendorf*) or a row along a road (*Strassendorf*), or from a hill-brow fortress in its ring rampart, perhaps also from encampments of wheeled nomads.

The quadrate town of Gaul or the Rhine usually became a bishop's city after the Roman Empire broke down, and a cathedral was often the synthetic expression of social life, and was thus in a dominant position, and the bishop's town often survived the period of impoverishment that followed the spread of Islam across the old Mediterranean trade routes. The town of the centre of the Paris Basin does not typically make so much of either castle or town hall or guildhalls, as of the cathedral.

With regrowth of trade after the period of impoverishment the commercial city was born and attained its clearest development in Flanders and N. Germany. Its roads leading to a harbour, its town hall on a central square, and guildhalls near by, its civic belfry and civic church are outstanding features, growing side by side, it may be, with a castle and a bishop's church.

There is interpenetration of these ideas and those of the Paris Basin along the northern borders of the latter.

There are also cases of cities growing around castles, a few in France, more east of the Rhine, where also the idea of the bishop's city is transplanted, and the idea of the merchant city has spread.

Further east the city is often either a transplantation of an idea from the west, or a growth under the influence of aristocratic and military churchmen or traders, and a cathedral in a castle enceinte may be the nucleus, sometimes as at Prag, standing out in contrast to the burghers' city. The castle-and-cathedral-nucleus is expressed most intensely in the Russian cities' Kremlins.

The regions where the castle-and-cathedral-nucleus occurs are the regions in which racial or cultural minorities create very sharp political problems, those in which bishops' cities with a Roman background occur include the regions of historic national organisation.

Cities definitely planned, usually in quadrates, have been founded at various times throughout the period of city development in most regions of Europe.

Dr. VAUGHAN CORNISH.—*The Rural Scenery of England and Wales.*

There are many types of beautiful scenery, but all have one common character, harmonious grouping. Given this condition the landscape is pictorial, but the introduction of an inharmonious element breaks up the picture.

In the small-scaled landscape of the undulating English plain rural architecture is focal in the view, and in all parts where a definite style of building has been established in early times it is desirable to build so as to carry on the pattern, or, if this be impossible, to build with unobtrusive form and colour so as not to break the pattern.

Tree-planting in a city presents no difficulty of design, for the forms of foliage, not being insistent, relieve the austerity of architecture without breaking the pattern, but in the straggling suburb confusion of forms obliterates both the beauty of the country and the beauty of the town.

The chief natural pattern in the English plain is provided by the rounded forms of broad-leaved trees, of which one extensive national woodland, the New Forest, still remains. Here it is desirable to discontinue all planting of conifers in order not to break the pattern and thus impair a picture so characteristically English.

The beauty of trees belongs to the nearer view only, and it would be a mistake, from the pictorial point of view, to plant upon the crests of bare uplands rising above the plain, whose unbroken skyline imparts the sense of magnitude to the view. Downs of the chalk formation have a continuity of undulation, unsurpassed in the world for grace of line, but it is a very vulnerable kind of beauty, soon shattered by hard mechanical forms, particularly when silhouetted on the skyline.

The great industrial population of the Midlands, Lancashire and West Riding has three regions of wild scenery in which to seek that refreshment of body and soul which is necessary to the welfare of dwellers in factory towns, the Pennine Moors, the mountains of North-West Wales and the English Lake District. The beauty of the Pennine Moors when the heather is out owes much to the circumstance that the warm tone of the flower is complementary both to that of the cloud on dull days and to the shadowed hillside on sunny days, a colour-grouping more effective than that of any green hill.

The volcanic formations of Snowdonia present the most arresting form of land relief, the range of mountain peaks and this region of natural beauty, the scene of heroic deeds, whose gates are guarded by ancient castles, might fitly be consecrated by the Welsh people as a national park for the cult of historic piety and the veneration of nature.

The effect of a lake upon the landscape is so dominant that even mountains appear to have a dependent grouping, and though Cumbria is the only land of mountain peaks in England, we call the mountainous region the 'Lake District.' Here the residents have long pursued the cult of scenery, and the problem of reconciling accessibility with preservation is engaging the attention of energetic organisers and generous donors who deserve the gratitude of the country.

The change of climate given by sea air determines the direction in which the majority of people seek change of scene, and moreover, the coast provides a greater change in scenery than the varieties of inland view.

The march of the waves upon the shore is a picture which never palls, and can be watched anywhere on two thousand miles of beach, but access to the splendid aspect of the sea from the cliff, with its vast expanse and unmatched horizon, is being restricted by enclosures which it is impossible to prevent in the present state of the law. Legislation to secure access to the cliff would be justified, for the outlook from the cliffs is the national heritage of an island people.

Mr. F. DEBENHAM.—*Problems of the South African Sector of Antarctica.*

The sector defined between 15° W. longitude and 80° E. longitude.

The General Problem.—Comparative ignorance of the continent in this sector. Reasons for neglect of the sector. Remote from centres of settlement. Scarcity of sub-antarctic islands. Inferences as to coast line from conditions met by early explorers.

The Meteorological Problem.—General thesis that Antarctic weather affects the Southern Hemisphere. No data available for the sector, but analogies with other sectors permissible. Chief characteristics of Antarctic climate. Possibilities of relations between seasonal variations in the southern continents of Antarctica.

The Ice Problem.—The nature and rate of discharge of ice from the Antarctic Ice Cap. Possibility of the existence of great ice barriers. General characteristics of inland ice. The problem is of general scientific interest without immediate economic bearing.

The Geological Problem.—No data whatever available at present. Peculiar interest

of South Africa with its great glacial deposits of Palaeozoic age in the constitution of the rocks of this sector.

Economic Possibilities.—Value of sector confined entirely to marine products, chiefly whaling. Brief sketch of whaling development in other sectors and application to the conditions in South African quadrant.

Conclusion.—Need for investigation of problems and methods of attack.

Thursday, August 1.

Prof. C. B. FAWCETT.—*The Location of the British Empire in relation to the Old World.*

The Old World here means those lands which were accessible to the civilised peoples of Asia and Europe before the development of trans-oceanic navigation, *i.e.* it consists of Europe, Asia and Africa north of the Sahara, together with their marginal island groups.

This Old World contains approximately half the land of the world (excluding Antarctica) and more than three-fourths of the human population. And it is mainly one continuous land area, in strong contrast to the widely separated insular and peninsular lands of Australia, Africa south of the Sahara, South America, North America and many islands, which together make up the New World. Hence the Old World is, and is likely to remain, by far the most important among the land areas of the earth.

In relation to the Old World the lands of the British Empire form two very incomplete concentric series.

1. The inner series is formed by the British Isles, the way-stations from Gibraltar to Aden, the Indian Empire, Ceylon, Malaya and Hong Kong. These lands lie on, or just off, the western and southern margins of the Old World land mass, and occupy important positions along its open-water coasts. Within them lie the 'mandate' territories of Palestine, Transjordan and Iraq.

2. The outer series is formed by Newfoundland and Canada, the British West Indies, the West and East African territories, South Africa, Australia, New Zealand and some Pacific islands. All these lands are parts of the New World and lie from 2,000 to 6,000 miles away from the central land mass of the Old World.

The lands of what I have just called the inner series together occupy about one-fifth of the total land area of the Empire; but, since India and the United Kingdom are by far the most populous divisions, this inner series contains nearly four-fifths of the Empire's population.

If, however, we distinguish the lands of the British Commonwealth (the self-governing States of the Empire) from their dependencies, we may note that in the Commonwealth only the British Isles are in our inner series close to the Old World continent. All the other Dominions are in the New World. Measured by mere area the British Isles occupy only one-sixtieth of the land of the Commonwealth, with perhaps one-tenth of its population capacity. At the present time, however, these islands contain about two-thirds of the white population of the British Empire, a proportion which is still overwhelming though it is steadily diminishing owing to the greater rates of increase of population in the younger Dominions. And when, as a result of this growth, the British Isles cease to be the most populous part of the British Commonwealth, the Empire will be to a much greater degree than it is at present a part of the New World, with the homeland of Britain as its outpost towards the Old.

Mr. R. O. BUCHANAN.—*Geographic Influences on the Dairying Industry of New Zealand.*

New Zealand stands second only to Denmark as an exporter of dairy produce, and provides an excellent illustration of how local geographic advantages may counter-balance such disadvantages as shortage of labour and distance from markets, the latter causing in turn the difficulties of expense, rapidity, frequency and regularity of delivery of supplies.

Distribution.—Distribution maps of New Zealand's dairy cattle show the enormous preponderance of North Island (1,087,866) over South Island (264,784), and the predominance in North Island of the following regions: South Auckland, especially the counties of Hauraki Plains, Piako and Waikato; and Taranaki, surrounding

Mount Egmont. Very important areas of smaller cattle-population density are North Auckland, the Manawatu-Rangitikei region of Wellington, South-western Hawke's Bay and the Wairarapa Valley. In South Island only Southland is really important.

Controls.—What follows has special reference to North Island. The geographic controls comprise climate, relief and soils, and these define not merely the distribution but also the methods of farm practice.

Climatic characteristics of the great dairying areas follow from the situation, shape and relief of the country, and comprise :—

1. Ample rainfall with winter maximum, strongly marked in the north, but with no hint of the characteristic Mediterranean summer drought.

2. Exceedingly equable temperatures with very mild winters. These characteristics promote all-year growth of luscious grass after the clearing of the original forest, and this incentive to specialised dairying is increased by the suitability of the kahikatea or New Zealand white pine for the manufacture of butter boxes. Inside the area covered by these suitable climatic conditions the intensiveness of production is dictated by relief and soils. Over 80 per cent. of the dairy cattle of the country are found below 650 feet elevation, but even these lowlands contain much rugged, broken country. The flat plains naturally show the greatest density of cattle. Of the soils the two richest types are river silts, which form notably the whole of the flood plains of Thames, Piako and Waikato Rivers, and basaltic soils, which cover the whole of the dairying area of Taranaki and are found in patches throughout North Auckland.

Methods.—In these specialised dairying areas the ample precipitation, mild temperatures and rich soils produce high cattle-carrying capacity on the natural growth of the grass alone. Hence farms tend to be small, but herds large, and the essence of farming practice is grass farming in the strict sense of the word. Supplementary feeding plays a small part, and is directed against the possibility of summer rather than winter shortage. The animals remain out of doors all the year round, the milking season lasts the whole year, and the labour shortage has been met by the adoption of machine milking, facilitated by the development of the abundant hydro-electric power resources.

Industrial Aspects.—The physical factors influence the organisation of the industry on its industrial and commercial sides. The specialisation of the Auckland Province on butter and of the rest of the dairying areas on cheese production is to be related partly to the milder winters of the north and the consequent greater importance of the Jersey breed, partly to the difficulty of establishing good roads in the soft, wet, stoneless silt soils of much of the best dairying lands, and the resultant preference for that type of production which makes least demand on transport. The peripheral character of the lowlands minimises land transport to the ports. The very distance of the country from its overseas markets has almost compelled the adoption of farmers' co-operation, under which system most of the dairy produce is manufactured. Finally, the small size of the country rendered easy the task of its unitary government in establishing a national system of regulation, including inspection of factories and grading of product, which has produced a uniform standard of quality.

The Future.—Great expansion is still possible both by utilising new areas, the most important of which is probably the Westland Plain of the South Island, and by increasing productivity on the lands already in use by further application of the principles of scientific breeding and feeding.

Prof. P. M. ROXBY.—*Expansion of China.*

1. The Chinese as a colonising race. Short résumé of Chinese colonisation in the past in relation to geographical conditions.

2. Factors affecting future expansion : (a) The economic situation in China ; (b) Social barriers to movement ; (c) Outlets.

3. A regional view of Chinese expansion : (a) Malaysia ; (b) Indo-China and in more detail (c) Manchuria and (d) Inner Mongolia.

A final estimate of the prospects of Chinese expansion and its bearing on the future of China and the Far East.

Mr. R. A. PELHAM.—*Trade between England and West Africa during the Early Years of the Eighteenth Century.*

The Royal African Company had been founded in 1672. In 1689 it lost its monopoly, and suffered severely from the competition of interlopers. Detailed

statistics collected from surviving journals and account books of the Company, customs accounts, &c. will be given to illustrate the nature and value of :—

(1) the exports from England to West Africa over a number of consecutive years, and

(2) imports into England from West Africa both direct and via the West Indies.

An estimate will be made of the relative contributions of the Royal African Company and the interlopers to the trade of the period.

Documentary evidence of the relations between the Company and the natives will be given, together with details concerning the exchange values of slaves, the extent of the liquor traffic, &c.

The particular climatic conditions under which the trans-Atlantic trade was carried on will be illustrated by extracts from the logs of some of the ships engaged.

Friday, August 2.

Joint Meeting (Sections E, L) on *The Teaching of Geography*.

(a) Mr. L. BROOKS.—*Report on the Teaching of Geography in England*.

Fundamental changes have taken place in geographical teaching during the past twenty years. These changes have been due to the gradual growth of a definiteness of aim, an individuality of method and a coherence of content which to-day characterise geographical study at its best. These characteristics are marks of the older disciplines, and it is their achievement which guarantees the position of geography as an important and indispensable element in education to-day.

It follows that if school geographical teaching is to have its full educational value the subject must be so taught in the classroom as to represent faithfully the spirit and character of the corresponding movement in the wider intellectual world, for it is only then that the items of knowledge communicated are given their true relation and significance, so that the subject as a whole makes its special contribution to the pupil's outlook and habits of thought.

Many lessons must be directed to the acquisition of skill in the use of tools and aids, *e.g.* map-reading and observations of the weather; many must be devoted to acquiring first-hand experiences, *e.g.* of river work, visits to places of geographical interest; but whether or not the teaching as a whole satisfies the conditions stated above can be tested in the treatment of three essential and characteristic elements which in geographical study are brought to one focus naturally and without forced attempt at correlation.¹ These are :—

1. The personality and possibilities of the locality.
2. The characteristics, needs and outlook of the people.
3. The nature, requirements and effects of their work.

Borrowing from Prof. Geddes, these may be expressed briefly as 'place,' 'folk,' 'work.' Geographical teaching, at its best, is recognised in the way the teacher deals, according to the age and attainments of his pupils, with the description of these three elements, with their relationships and interactions, with the synthesis they compose, and with their expression, in writing and in maps, in the geographer's characteristic way.

It is obvious that the work presented at different stages must be carefully graded. Much current teaching tends to be too difficult in the earlier stages and too elementary at the post school certificate stage. The desire to teach 'cause and effect relationships' and to be always finding explanations frequently utterly spoils the teaching at the primary stage, *e.g.* 7 or 8 to 11+. At this stage the teaching of 'place, folk, work' should be concerned mainly with the giving of accurate impressions and pictures through descriptive teaching illustrated by lantern slides, pictures, &c. The wise teacher will also make sure that his pupils acquire an adequate background of facts.

From 11+ to 16+ is the five years' course of the normal secondary school. Descriptive teaching is still exceedingly important, but during these years the teaching should be more definitely regional in character, and a definite and progressively arranged attempt should be made to study the interactions and relationships of the

¹ 'Geography and Citizenship.' P. M. Roxby.

three elements. In order to do this the results of other sciences will be drawn upon, and it will be necessary to teach many of the processes of physical geography.

The third stage of school teaching is the advanced course from 16+ to 18+. At this stage climatology and physical geography may be studied as such, and the elements of map-making may be added to the practical work. The main task, nevertheless, will continue to be the study of the relationships and interactions of 'place, folk, work.' Studies of a 'world' and 'continental' order may be continued, but this stage is eminently suited for a more advanced regional examination of smaller areas, *e.g.* of the order of Western Europe, the Mediterranean lands or France, on the one hand, and the home region, or one which is capable of first-hand study, on the other. This stage is also the proper time for systematic teaching of the present conditions of human life in an area as an evolution of 'geographies' of the past. Below the advanced course stage the teaching is mainly concerned with *present* conditions and systematic teaching of an 'evolutionary' character of either past or present would be premature and out of place.

Two important points of teaching method arise from what has been stated above :—

1. The interests of school pupils are chiefly concerned with the life and work of man, so that the wise teacher gives first place to 'folk and work,' a minor unity which stands out as the growing or gathering point of the teaching.

2. In general, the study of 'place,' apart from descriptions of 'personality and possibilities,' is subordinate to the study of man and his work. Below the advanced course stage separate school courses of lessons on climatology or physical geography are out of place.

Putting these two together we have a clear direction for a general method of teaching. It is the task of the teacher to describe as accurately as possible how man 'lives, moves and has his being' in the different regions (and this is almost the full task up to the age of 11+), and then to select from the physical basis the factors which must be introduced in order adequately to understand the relations and interrelations of human life and physical conditions. The usual method of following a logical order of treatment (position and size, physical features, climate, natural vegetation, &c.) is wasteful of time and effort; it frequently leads to inaccurate generalisations and statements, and often fails to give the essential idea of unity in a living whole.

The remainder of the paper will attempt to show how the principles formulated above may be worked out in the teaching of the Lancashire cotton industry at each of the three stages of teaching.

(b) Prof. F. E. PLUMMER.—*Memoranda on the Teaching of Geography in South Africa.*

Higher or post-primary school education in the Union of South Africa is under the central direction of the Education Department set up in each of the four Provinces, and is subject to final control by the several Provincial Administrations.

Apart from financial considerations, the curricula followed at the various post-primary schools depend very largely upon the regulations governing the school-leaving examinations. The Matriculation examination of the Universities of South Africa and the School-leaving Certificate examination are conducted annually at suitable centres throughout the Union by the Joint Matriculation Board, each under two alternative sets of regulations known respectively as the Interim Regulations and the New Regulations. Geography is an optional subject in each of these schemes, but may be taken only on the lower grade.

Normally, six subjects may be offered for examination, but under the New Regulations for the Matriculation Certificate either six or five subjects may be offered.

Typical curricula followed in most Transvaal schools under these regulations are :—

Six subjects.—English, Mathematics, German (or French), Science, History, Afrikaans.

Five subjects.—English, Mathematics, Science, Afrikaans, History (or French or German).

In the Matriculation Certificate examination, under both sets of regulations, Geography clashes with either one of the official languages of the Union or with History.

Unlike those for the Matriculation Certificate examination, where the subjects are divided into six groups, from each of which the candidate offering six subjects must

select one, whilst if five subjects are offered they must be selected from not less than four groups, the regulations for the School-leaving Certificate allow for the selection of the six subjects offered by the candidates from four groups. But whilst there is no specific regulation against a candidate offering Geography as one of his subjects, he can do so only if he omits one of the important subjects mentioned in the typical curricula above. Under the New Regulations for the School-leaving Certificate examination, History and Geography combined appears as a compulsory subject, and it is not likely that Geography would be chosen by a candidate in addition.

The Junior and Senior Certificate examinations of the Cape Province, and the Transvaal Secondary School Certificate examination, stages I and II, are provincial examinations held in two parts. The regulations have been approved by the Joint Matriculation Board and the question-papers are moderated by the same moderators as the papers for the Matriculation examination. The regulations for the Transvaal examination are identical with those for the Matriculation examination, but the Cape examination differs in some important respects so that increased opportunities are provided for the selection of Geography as an examination subject, but this is made possible chiefly because Mathematics is an optional subject. As Mathematics is an exceedingly valuable subject to the serious student of Geography, the advantages of this scheme to the furtherance of geographical teaching are not real.

The following observations on the teaching of Geography in post-primary schools are based, in part, upon information readily given by the Directors of Education in the various Provinces, to whom I am very greatly indebted.

Usually in those schools where provision is made for advanced teaching in Geography, the enrolment is such as to permit of parallel courses and classes to be conducted. In such schools, scholars selecting Geography generally drop either History or Afrikaans or Drawing from their curricula. The relative importance of these subjects is indicated in the table giving the number of candidates taking the Transvaal Secondary School Certificate examination :—

	1922	1923	1924	1925	1926	1927
Candidates	735	1,056	1,201	1,172	1,219	1,011
Afrikaans, A. & B. ...	311	618	929	1,063	1,126	950
History, A. & B. ...	640	973	1,081	1,020	1,056	861
Geography	5	7	15	54	50	61

The table shows that a negligible number of candidates in the Transvaal take Geography up to Matriculation standard. Only three schools out of forty in the Transvaal provided for the teaching of Geography up to Matriculation standard in 1928. As a general rule, it may be stated that instruction in Geography stops at Standard VI in the Orange Free State.

The chief causes for the dearth of geographical teaching in the Union of South Africa appear to be :—

1. Lack of opportunity and encouragement to pupils to take Geography as a Matriculation subject.

2. It is the last subject to be placed in the Secondary School curriculum, and it suffers from a lack of systematisation of syllabus and of textbooks.

3. No provision is made for Geography to be taken on the higher grade in any Matriculation examination.

4. In the present overcrowded curriculum it can only be taken as alternative to History or Afrikaans. Custom and sentiment seem to prefer History to Geography.

5. Modern Geography teaching has made tremendous strides, and teachers of the 'old school' appear to be quite unable to judge its merits. Thus, this subject has to contend against a deadweight of prejudice.

6. More equipment and materials are necessary for the proper teaching of Geography than for History or Afrikaans, and many schools do not attempt to provide higher instruction in Geography on the ground of expense.

7. Due to the demand for economy and to the dearth of specialist Geography teachers in the past, scarcely any schools have even one teacher specially interested in Geography.

8. The prevailing system of education, dominated as it is by examinations, tends to narrow down the lessons given in schools to such as will be directly profitable in

mark earning. No time is allowed for excursions, for discussions, for the specialised study of a district or for the individual enterprise of teacher and pupil.

9. The teaching of Geography in Primary Schools needs improving. Very many children entering Secondary Schools cannot use an atlas.

10. My observation of students in training leads me to think that they are studying and trying to teach Geography without a sufficiently sound foundation of knowledge to enable them to benefit by the advanced work.

Suggestions for improving the position of Geography as an educational subject in the Union.

1. Revision of the regulations for school-leaving examinations so that Geography may be offered as a subject in addition to History and Mathematics.

2. Increased facilities for intending teachers to study Geography at the various Universities and University Colleges.

3. Vacation and refresher courses.

4. Advice on, and expert assistance with, the equipment of classrooms with suitable apparatus, textbooks, reference books, readers, &c.

5. The provision of means whereby teachers, particularly country teachers, may receive the most recent information of events and of facts of a geographical nature.

Notes and suggestions forwarded by other members of the committee.

A. Prof. Wellington, Mr. Robb and Mr. Prescott.

'... the Matriculation regulations are the great stumbling block. So vital do we consider this that if these regulations were altered, making it possible to take History and Geography together, we feel that the road would be open to immediate progress in this direction.'

'... The Provincial authorities of the Transvaal ... encourage Geography strongly.'

'... During the past seven years nearly 150 teachers have passed their three years' courses here (University of the Witwatersrand) ... They have gone to other subjects in the schools because of the lack of opportunity to specialise in Geography ...'

B. Prof. Serton.

'... I think the present regulations give a somewhat better chance to Geography than is indicated in your statement. There still is, in my opinion, far too much physical and far too little human Geography in the different syllabuses. Nearly every pupil takes a lively interest in the human element, while only a few are sufficiently provided with knowledge of Physics to be able to do good advanced work on the physical side. The result is that things are learned by heart instead of being understood, and, of course, such kind of work cannot be expected to arouse much interest.

'I am thinking here especially of certain requirements on the meteorological side and of the remarkable obsession of the plane table, which is still haunting the Cape syllabus. It is manifestly impossible to make our schoolboys surveyors—yet for a phantom like this a great deal of useful and really practical work has to be omitted.'

C. Mr. R. M. Jehu, Head of Department of Geography, Natal University College.

'... A large majority of the students who take the First Year Course in Geography in my department ... have 'little or no previous knowledge of the subject ... Only in very few schools is Geography taught up to Matriculation stage ... It is certainly high time that the Provincial Educational Departments were made to realise the importance of Geography, and its place in the school curriculum.'

(c) Prof. J. L. MYRES.—*The Correlation of Geography with History and Literature.*

All education has two main aims, the formation of habits of intellect, taste, and conduct, and the presentation of current experience of what goes on around us in this world, and the way people behave in it. Now these habits, and those accumulated experiences, have been acquired both somewhere and somewhen. They have, that is to say, their historical and geographical aspects, in addition to their quality as elements respectively in orderly society and in systematic knowledge. Since the general acceptance of the hypothesis of evolution, astronomy, geology, and biology have become no less historical sciences than philosophy or the study of institutions, literatures, and schools of art; and increasing use is made of historical presentation of the growth of

the fabric of knowledge in these subjects. It has not, however, been so generally recognised in practice, that such subjects have also a geographical aspect of similar educational value; being concerned as they are, with the distribution of certain physical facts and forces—from light and heat to organic life—and consequently of the natural objects wherein they are manifested to us. Still less, till recently, has it been realised that not only the races of mankind, but every manifestation of human desire and will has likewise its geographical distribution; it can be 'mapped' and compared with other mappings; and the 'reading' of such maps is as essential to a liberal education as the reading of foreign languages or mathematical symbols. Geography, then, like history, is not so much one of the departments of science, as a mode of interpretation, criticism, and application, available in all departmental sciences, and chiefly concerned with the regional correlation of the facts and processes with which they severally deal both in theory and in practical life. It would seem to follow that geographical presentation, like historical narrative, can hardly be introduced too early in the process of education; and it certainly never is outgrown. Every child inevitably is becoming some sort of a geographer, as he is becoming some sort of a historian, in respect of his own explorations and memories; the only question for the teacher is, how to make as good a geographer and historian as natural ability allows. The starting-point is in the child's immediate unavoidable surroundings, his home, school, and district, in all their wealth of illustration both of the 'way things happen' and the 'way people behave,' which are the raw material of history and geography throughout. Map-making, the necessary preparation for map-reading, provides the framework for the record and display of every kind of wayside observation—'every-way' knowledge, it may be called—as the calendar and diary correlate the memories of 'every day.' Here, from the first, too, geographical training joins forces with literary, in the appreciation of felicitous and intimate description of natural objects and occurrences; as literature joins with history in the felicitous commemoration of events and personalities. And other arts—in particular the greater schools of landscape and genre painting—contribute similarly to geographical interpretation, as portrait painting, and the portrayal of occasions and manners, to historical.

But geographical teaching, of the kind here projected, presumes geographical thinking, and some geographical training in the teacher. For the teaching of history, the corresponding contention is undisputed; still more so, for the teaching of languages or branches of science; and of this the moral is that geography is no longer a 'school subject' merely, but as worthy as history or literature of recognition at the University stage.

Discussion: Prof. P. M. ROXBY, Mr. G. FLETCHER.

JOHANNESBURG.

Wednesday, July 31.

Prof. J. H. WELLINGTON.—*Physical Influences in the Human Geography of South Africa.*

Mr. A. G. OGILVIE.—*Report of Committee on the Geography of Tropical Africa.*

Miss M. R. SHACKLETON.—*Continentality of Climate in Relation to Human Geography in Europe.*

An examination will be made of the usefulness to geographers of the climatologists' views on continentality in regard to Europe.

Viewed from a world standpoint and in regard to the general effect on human modes of life, the 'continental' climate of *e.g.* the Moscow region seems to differ more from the 'continental' climate of *e.g.* the Kirghiz steppe than it does from the 'oceanic' climate of *e.g.* the British Isles. There seems a fundamental difference to the geographer between areas of continental climate with sufficient rain for agriculture and close settlement, and those with so little rain that, at best, only a nomadic population can be supported. From the world viewpoint, almost the whole of Europe is

sufficiently subject to ocean influences for the term continental climate to be misleading as applied to the mass of the eastern section.

Viewed in the greater detail required for the regional analysis of a continent there are obviously important differences between the climates of *e.g.* Dublin and Moscow. It is doubtful, however, whether the points of difference stressed by climatologists should be given the same relative importance by the geographer.

Since, however, the boundaries drawn by climatologists between the eastern and western European sub-types are usually quite arbitrary, even where a transition zone is inserted, a door seems left open for an examination of the subject from another angle. A study of the two sub-types where these are fully developed, and of their more important direct and indirect influences on man, should also throw light on the problem of the transition area between them, especially if less attention is paid to normals and more to variability from year to year.

Prof. J. H. WELLINGTON.—*The Vaal-Limpopo Watershed.*

Dr. VAUGHAN CORNISH.—*The Scenery of the Cape Peninsula.*

SECTION F. ECONOMIC SCIENCE AND STATISTICS.

CAPE TOWN.

Tuesday, July 23.

Prof. R. LESLIE.—*Coloured Labour and Trade Unionism in Cape Town.*

European trade union leaders in Cape Town have constantly opposed any colour bar within the local unions, as they saw that their bargaining power, except in engineering, would be very small unless the coloured members were included. Thus the skilled coloured man has, at the moment, a strong position in the unions.

TRADES IN WHICH APPRENTICESHIP COMMITTEES EXIST.

	Estimated percentage of coloured members.	Period of Apprenticeship (Years).	Minimum School Standard.
Engineering	Practically none	5	7
Printing	30	7	7
Leather	60	5	5
Building	—	5	6
Bricklayers	50	—	—
Carpenters	40	—	—
Painters	90	—	—
Plasterers	90	—	—
Furniture	90	3 to 5	6

Other unions in which there is a large percentage of coloured members are : baking, 80 ; biscuit making and packing, 60 ; garment workers, 80. There are two registered unions which are essentially coloured—dock workers and laundry workers—though the latter has four or five white members.

European boys show no unwillingness to enter trades in which there is a high percentage of coloured workers. European girls dislike the idea of working alongside coloured girls. Difference of attitude towards coloured workers is also shown by a

comparison of the evidence given to the Economic and Wage Commission, 1925, by the Cape Federation of Labour Unions and by the Afrikaanse Christelike Vrouwe Vereeniging.

Present proportion of coloured workers in the skilled trades is not likely to continue.

Apprentices attending the Cape Technical College :—

	1928.		1927.		1926.	
	White.	Coloured.	White.	Coloured.	White.	Coloured.
Engineering . .	559	15	390	10	293	3
Printing . .	103	12	92	10	84	3
Leather . .	—	—	—	—	—	—
Building . .	404	72	282	56	214	18
Furniture . .	215	295	235	231	143	207

These figures, and the very small number of pupils in coloured schools who reach standard 6, seem to support the view of some trade unionists that in ten or fifteen years the skilled trades will be in the hands of Europeans. It is more probable that the coloured man will continue to enter the skilled trades, but that the proportion of whites will increase.

Trade union action in Cape Town has not injured coloured labour, skilled or unskilled, by colour bars. Any injury done is that which arises in any country when a trade union is able to reserve to its skilled workers work which could have been done by semi-skilled workers.

Prof. A. PLANT.—*The Anti-dumping Regulations of the South African Tariff.*

Wednesday, July 24.

Joint Discussion (Sections F, M) on *The Problem of Stabilising Agricultural Prices, with special reference to Control Boards, Equalisation Funds, and other Methods of Price Regulation.*—Mr. R. B. FORRESTER, Mr. R. J. THOMPSON, C.B., Dr. J. M. TINLEY.

Mr. R. B. FORRESTER.—Leaving on one side the monetary aspects of this subject, it may be stated that recent marketing movements dealing with supplies fall into two groups. There is (1) 'straight marketing work,' which aims at improving marketing methods and organisation by the use of standards, collective bargaining, sales agency, &c.; (2) there is the attempt at some control of price or control of output; this phase of marketing is commonly prominent in most farm relief schemes, discussions of stabilisation and plans for raising prices. Special consideration may be given to the economic limitations of such agencies as pools, export control boards, &c., as influences upon prices and of such plans as the McNary Haugen scheme of surplus control and of equalisation funds. Possible temporary success of such schemes but vital difficulty lies in the question of control of production and output.

Mr. R. J. THOMPSON, C.B.—The fundamental importance of monetary causes as affecting both agriculture and industry is now fully recognised, but this aspect lies outside the scope of agricultural policy. Second aspect is the natural instability of agricultural prices; one development designed to meet this difficulty is the organisation of co-operative selling organisations such as the wheat pools of Canada, the New Zealand Meat Producers' Board, the Danish Co-operative Selling Agencies, and similar bodies. This method is specially applicable with exporting countries, but a second suggestion is the converse, the organisation of buying, which would be applicable to importing countries such as Great Britain. The conception involves the establishment of a national purchasing organisation which would control imports. Consideration may be given to the chief points which arise in such a scheme such as State monopoly, size of the undertaking, &c. Origin of much of this discussion lay in the experience of war-time control, but this does not give a reliable indication of the

results to be obtained in peace. Special proposals on similar lines were put forward at the Imperial Conference, 1923. The possibility of agreements between producers' and consumers' co-operative associations is an allied policy. Conclusion as to the feasibility of the method of control of imports.

Dr. J. M. TINLEY.—(1) *Introduction*.—Reason for importance of problem. Question of surpluses. Depression in agriculture.

(2) *Meaning of Stabilisation and Objects*.—Difference between problem of season, annual and cyclical fluctuations in price and production.

Commodities on import or local basis and commodities on an export basis. Perishable and non-perishable commodities have different problem. Elasticity of supply and price forecasting.

(3) *Difficulties in way of Stabilisation*.

(a) Inadequate education of farmers—inaccurate price and production (crop-reporting) data and insufficient research into price-making factors.

(b) Disorganisation of marketing machinery for interpreting supply and demand factors.

(c) Difficulty of erecting machinery to stabilise prices. Composition of controlling organisation. Necessity for avoiding politics and basing decisions on facts of case. Steps to control production which is essential to stabilisation of prices. Financing.

(4) *Special Problems in South Africa*.—Low cost of production of most export commodities. Violent fluctuation in production due mainly to climatic conditions. Disorganisation of local markets. Lack of fundamental statistical data.

(5) *Possible Developments*.—Collection of price, production and other data. Research studies of elasticity of supply for different commodities. More efficient means for acquainting farmers with economic principles involved. Development and improvement of co-operative movement. Eventual formation of Boards for different commodities. Interpretation of economic data and advice to farmers. Control through credit and fertiliser distribution.

Thursday, July 25.

Joint Discussion (Sections F, H) on *The Economic Competition between Advanced and Backward Peoples*.—Prof. H. CLAY.

Friday, July 26.

Prof. J. W. F. GROSSKOPF.—*The Agricultural Land of South Africa and its Users*.

During the last thirty to forty years South Africa has rapidly been passing out of the 'pioneer stage,' although the process is by no means complete in all sections. The mineral wealth cannot continue to be tapped as it has been. Leaving aside the question of the mechanical industries, it is being recognised more and more generally that a larger output—not only absolutely, but relatively—of pastoral and agricultural products, is essential to a healthy economic life.

As South Africa is not rich in natural resources compared with many other 'new' countries, the most economic use of the national soil is of the utmost importance. But immense portions of the Union suffer from an insufficient and irregular supply of water; whilst irrigation—in a country possessing no great rivers—can practically aim at little more than collecting as much as possible of the rain that does fall over a wide surface, and utilising this for a very small proportion of the land.

The typical form of settlement since the eighteenth century has been that of isolated homesteads on very large farms, chiefly due to the scarcity of open water and to the sparseness of the aboriginal population. The pastoral tradit on dominated the 'trek' towards the north. A wasteful use of land resources was usual; and a very strong individualistic spirit of private ownership, and a greed for large holdings (often accompanied at a later stage by land speculation) became common. The advent of more modern conditions did not bring about a rapid change.

As population grew, the poorer and less efficient members of the white community were pushed into more distant or inferior sections; or they obtained the use of land from the larger owners under rather informal agreements.

Certain portions of the aboriginal population developed into permanent or seasonal farm labourers, whilst the social and economic status of the landless white people grew steadily worse. They had not developed into agricultural labourers, whereas land was only obtained with increasing difficulty.

Under existing conditions of land-holding and farming the rural areas of South Africa are already unable to absorb their natural increase of white population. The European population is faced to-day by a strong rural exodus, one of the main causes of the 'Poor White Problem.' On the other hand, the areas reserved for tribal natives have also become badly congested, thus causing a spirit of restlessness and forcing many natives out to compete still more with the impoverished whites.

Whilst part of the surplus rural population, European and non-European, can be absorbed by town industries, it is clear that access to the use of the land must be found for great numbers, and that our laws and our policy relating to land, its ownership and its use, will have to be thoroughly revised.

Mr. D. T. JACK.—*The Problem of the Future Value of Gold.*

The general return to gold standard conditions within the last five years has again directed attention to the problem of the stability in the value of gold over long periods. There are reasons for the view that this problem is likely to acquire still greater importance, more particularly in virtue of the sensitiveness of international trade to movements in the level of gold prices and in view of the magnitude of public and international debts. Expert opinion has been sharply divided as to the probable course of gold prices on the assumption that no special efforts at 'control' are made along such lines as have been suggested by Irving Fisher or Lehfeldt. Special consideration will be given to the views of Cassel, Keynes, Kitchin, Lehfeldt and Gregory. World gold production has fallen in comparison with pre-war years, but the further decline which has been anticipated has not yet occurred. More importance attaches to the magnitude of the monetary demand for gold, and it is suggested that Cassel's pre-war estimates require modification. On balance the conclusion is reached that central banking economy is imperative if a rise in the value of gold is to be avoided.

JOHANNESBURG.

Wednesday, July 31.

Dr. J. E. HOLLOWAY.—*The Demographic Position in the Union of South Africa.*

Racial.—European and non-European. British, Dutch and other European races. South African and foreign born.

Geographical.—Predominance of non-Europeans in certain areas. Distribution of population between urban and rural areas.

Occupational.—The occupational groups; the coincidence of racial and occupational boundaries.

Vital.—The natural increase and masculinity of the population.

Migrational.—Internal and foreign movement of population.

The treatment will be based largely on the statistics of the population of the Union.

Dr. S. H. FRANKEL.—*Road and Rail Transport in South Africa.*

Notwithstanding the fact that oil has not yet been discovered in South Africa, and that the cost of imported oils, petroleum products and motor fuels is still extortionately high, there has been a development of road motor transport which, if the unorganised condition of South African roads is taken into account, has, in comparative extent, probably been second to few European countries with similar conditions. South Africa, just as other 'young countries,' has passed the stage where, with a handful of white settlers spread over wide areas of the country, the road problem was merely to keep long road lines passable by ox- or mule-wagons for a few tons of produce a year. Similarly it has passed the stage where, whenever an extended form of organised transport was necessary, a branch railway line was built, more to satisfy local expectations than in accordance with economic considerations which

would warrant the construction of the line, or would have indicated the correct route to follow. In this sense there can be no doubt that South Africa has reached the peak of its railway expansion. The problem is now one of organising a national highway system, and co-ordinating it with the State railway system already in existence. This paper considers the existing obstacles, political, legal and financial, to this, and the ways in which they could be removed. It emphasises the need for a central authority to deal with these and allied matters, to consolidate the regulations affecting transport throughout the Union, to unify provincial ordinances and Union Statutes with reference to the taxation of road users, and to establish a road fund into which monies so raised should be paid.

Just as the haphazard construction and maintenance of roads and the building of uneconomic railway lines can no longer be permitted, so the unregulated and frequently haphazard fixing of railway transport charges, which the paper shows has taken place in the past, must in the interests of the Union be prevented in future. Consideration of the problems of the relation of the State railways to organised and unorganised motor transport undertakings, of the present legal powers and obligations of each, and of the present and prospective competition between them, leads to the conclusion that they cannot be solved by mere 'rule of thumb' legislative efforts. They can no more be solved by restrictive legislation preventing road motor development and competition than by merely leaving road motor transport unregulated. There is the most urgent need, therefore, for a national body, such as a Ministry of Transport, to co-ordinate and control all the transport services of the Union. There is need also for an impartial national body to act as a board of appeal, and to adjudicate upon, and where necessary fix, the charges of the various organised transport undertakings, so as to safeguard both the public and the transport undertakings themselves, against unfair practices and competition. The paper outlines how these national bodies could in the interests of the Union best be constituted and appointed, what their functions should be and what problems they will have to deal with.

Thursday, August 1.

MR. JOHN MARTIN.—*Group Control in the Gold Mining Industry.*

MR. W. H. CLEGG.—*Banking in South Africa.*

Friday, August 2.

Presidential Address by Prof. H. CLAY on *The Public Regulation of Wages in Great Britain.* (See p. 119.)

MR. W. H. HUTT.—*Collective Bargaining and Distribution.*

The object of this paper is to controvert the suggestions (a) that there is some portion of the normal remuneration of labour which, in the absence of collective bargaining by labour, is, or can be, transferred to the remuneration of other factors of production owing to labour's 'disadvantage in bargaining'; or (b) that combination, by increasing labour's 'bargaining power,' enables it to acquire a part of the normal remuneration of some other factor.

Belief in the Wages Fund formula did not prevent the classical economists from having a vague belief also in the 'disadvantage' of uncombined labour. The attack on the Wages Fund by trade union apologists in the late sixties was merely incidental to their attempts to rationalise these vague ideas about labour's disadvantage. In those attempts they had recourse to exceptional and unlikely examples which showed that they were groping confusedly towards a notion of the indeterminateness that may arise in isolated individual transactions or under what has since been called 'bilateral monopoly.' But competition on both sides was generally blamed for the workers' disadvantageous bargain. The indefiniteness of isolated bargains had been realised earlier but dismissed as unimportant. From 1867 the development of the idea of indeterminateness can be traced through one Jacob Waley, Thornton, Fleeming Jenkin, Edgeworth, Sidgwick, Böhm-Bawerk and Marshall to modern writers. Those mathematical economists who have treated the conception most carefully would probably agree that it is of little practical importance as regards *distribution in general*; for such indeterminateness will not apply merely to the wage bargain; and

although one can *conceive* of particular cases in which such indeterminateness might be important in this connection, as, for example, where the inelasticity of demand for the contribution of a producing group makes possible a change in the division of the value of the product without resort to restriction of numbers (*e.g.* by restriction of output and work-sharing devices, such as short time by a trade union), yet the demand for labour, for instance, is seldom likely to be inelastic in the long run. For this and other reasons which will be elaborated later, it seems that, in practice, gains effected through combination, on both sides, are secured at the expense (a) of excluded competitors, (b) of the consumer. From these and other considerations will be deduced an explanation of the widespread tendency, observable since the beginning of the nineteenth century, towards what might be termed 'tacit joint monopoly,' such as the protection of the 'good' or 'generous' against the unscrupulous 'employer,' the existence and significance of which phenomenon has, perhaps, been insufficiently recognised.

SECTION G.—ENGINEERING.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 428.)

CAPE TOWN.

Tuesday, July 23.

REFRIGERATION:—

(a) DR. EZER GRIFFITHS, F.R.S.—*Description of Latest Work in Britain: Refrigeration Research for the Food Investigation Board.*

The work has been planned by an engineering committee of the Board and carried out at the N.P.L. It includes a study of the heat-insulating properties of materials used for the insulation of refrigerated ships and land stores. The thermal conductivity and moisture absorption of various substances have been determined. Mechanical strength tests have been made on cork board.

Attention has been given to the testing of small refrigerating plants for domestic use. Representative temperature measuring outfits of the distant reading type were submitted to a series of tests and recommendations made for various modifications. A new design of resistance thermometer outfit has been constructed.

A study has been made of the Ewing ball and tube flowmeter using various fluids. Some commercial types have also been studied on a small scale.

Consideration has been given to the question of humidity measurements at low temperatures, and a number of modified forms of hygrometers of the wet and dry bulb, the dew-point and hair type devised to meet special requirements. In addition, other instruments required for biological investigations have been devised, and mention might be made of a dew deposition recorder which records the occurrence of dew deposit.

Certain thermophysical constants required for the completion of entropy-temperature diagrams have been determined.

(b) MR. E. A. GRIFFITHS.—*Description of Recent Work in South Africa.*

COL. J. G. ROSE and PROF. DUNCAN McMILLAN.—*Alcohol Mixtures as Fuels.*

Wednesday, July 24.

ROADS AND PROBLEMS OF TOWN PLANNING:—

(a) SIR HENRY MAYBURY, K.C.M.G., C.B.—*The More Recent Changes affecting British Highways.*

A country achieves the solution to its own Highways and Traffic problems, based upon its own special conditions of topography, climate, population, &c. The more recent changes affecting British Highways may prove of interest.

The British Road System within the last ten years has become stabilised and secured. A financial scheme has been evolved and extensive works of construction

put in hand—surface conditions have been rapidly improved, and road transport both for passenger and industrial requirements is becoming more clearly defined and established.

Legislation of an important nature relating to roads and traffic has recently been passed. The railway companies have now secured powers enabling them to provide road transport services in conjunction with their railways—thus increasing their efficiency as common carriers. The Local Government Act or 'Derating Bill,' introduced last year, contains important sections affecting road administration, the tendency of which is to dispossess the smaller district Councils of highway control, placing the responsibility upon the larger Local Government Units, i.e. the County Councils and the County Borough Councils.

There is a gradual abandonment of the smaller tramway undertakings, and their replacement by motor omnibus services. Passenger transport systems have now penetrated into the most remote parts, linking up the small villages with the nearest market and shopping towns. These services are generally efficient and even luxurious.

The principles of Town and Regional Planning are now being applied, so as to provide for future road requirements by the sterilisation of the necessary land.

Attention is drawn to changes in social and housing conditions, and the part played by road traffic in relation to this, and emphasis is given to the popularity of the cheap and mobile small motor-car of 7 to 12 h.p.

A table is appended showing the drop in the average horse-power of the private motor-car from 16·8 in 1921 to 12·9 in 1927, thus indicating the popularity of this small type. A table is also given showing the comparative annual taxation of three distinctive types of motor vehicles in various countries of the world.

A Royal Commission on road transport now sitting has been considering the co-ordination of transport facilities in well-defined areas of the country, and important developments are expected along these lines.

The Paper concludes with some notes on the volume of road traffic, and factors bearing on road accidents, and their reduction.

Mr. D. E. LLOYD DAVIES.—*The Road Transport Problem in South Africa.*

Sir HENRY FOWLER, K.B.E.—*The Problem of Motor Transport in Underdeveloped Country.*

As a result of the recommendation of the Colonial Office Conference in 1927, and the Special Conference subsequently appointed by the Empire Marketing Board in December last, a small Directing Committee was appointed by the Secretary of State for Dominion affairs, and for the Colonies. This committee has been set up to study the assistance which mechanical transport can give to the economical development of the overseas Empire.

There are at present large tracts of country throughout the Empire which cannot be properly developed until its products, existing and potential, can be economically transported to points at which they can be consumed or used.

It will be realised that in spite of the great advance made in recent years in mechanical transport, the problem set out above is one of great magnitude and difficulty. At the very beginning the question of the roads available or which could be economically constructed has to be considered. This is a difficult matter in spite of the recent development of multi-wheeled and track vehicles. One of the problems is the question of a large unit, as it is probable that only by these means that loads which would not 'carry' heavy transport costs could be dealt with. Beyond this the fuel suitable and available, the class of labour which can be employed, and numerous other problems have to be considered. The committee have to collect information on the conditions to be met with in various parts of the Empire, and it is hoped that the discussion on the Paper itself will lead to some of this being given.

Thursday, July 25.

Mr. J. D. WHITE.—*Road Transport in South Africa.*

Lt.-Col. PHILIP JOHNSON.—*Transport Costs in Roadless Countries and the Possibilities of Mechanization.*

The finding of a means of movement over land intermediate between the minor means of all kinds with small load capacities, and the arterial railway train with a

load capacity of 500 or more tons, concerns closely all newer countries in which, being mainly agricultural, the demands for transport are too intermittent to justify more intensive railways or roadways.

Where, say, 10s. is available for the transport of maize to a market, then if the transport cost is 1s. a ton-mile the maize can be grown economically up to 10 miles from the market; but if 6d. a ton-mile, up to 20 miles away, the area of the circle around the market within which the maize can be profitably grown being thus not doubled but quadrupled.

Porterage, 5s. to 1s. 6d. per ton-mile; pack animals, 5s. to 2s.; bullock wagons, 1s. 6d. to 9d.; mechanical vehicles carrying 1 to 3 tons, 2s. to 1s. These costs by these minor means compare with 2d. roughly by rail; moreover, the expense of the damage to routes by bullock-wagons, and in the case of mechanical vehicles with small load capacity, the cost of road construction or repair does not appear in these costs.

There is thus a gap in the transport system between the mechanical vehicle with a daily ton-mile capacity of under 100 and the railway train with a like capacity of 150,000. This cannot be bridged economically by wheeled vehicles with load capacities of 5 to 15 tons, chiefly because these transmit too high a pressure to the ground, and thus destroy the surface.

There is every hope, however, that this gap may be bridged by the roadless train on the lines of a vehicle having an average speed of 5 miles per hour, a turning radius of 100 feet, a drawbar pull enabling the vehicle to cope, fully laden, with gradients up to 1 in 15, and the capacity to negotiate water up to 4 feet in depth. Each of the four trailers to be of 25 tons capacity, and mounted on girder tracks having a remarkable road-rolling effect. The tractor to weigh about 25 tons, to be equipped with a Diesel engine of 300 to 400 h.p., and mounted on tracks of special design to give the adhesion necessary for the drawbar pull required, the joints of these tracks embodying a novel principle of construction consisting in the use of rubber in compression, thus dispensing with the wear and tear previously experienced in the use of the pin-joint. No part of the vehicle to impose upon the ground a greater pressure per square inch than 12 lbs. It is estimated that the cost of transport by this roadless train could be reduced to 2½d. or 2d. a ton-mile.

The alternative of the multi-wheeled road train is mechanically possible, but objections to this type are:—the high first and maintenance cost; the loss of power involved in the transmission of the drive from one end of the train to the other, the high pressures transmitted to the ground by the wheels; even if these pressures be reduced by multiplication of the wheels there still remains the absence of a flat surface of contact with the ground.

Dr. C. V. VON ABO.—*Some Engineering Problems of the South African Railways and Harbours.*

Mr. M. M. LOUBSER.—*Engineering Problems (Mechanical) in connection with the 3 ft. 6 in. gauge, South African Railways.*

Friday, July 26.

Prof. A. E. SNAPE.—*University Training in Structural Design and Practice.*

Mr. J. C. HAWKINS.—*A Review of Irrigation in South Africa.*

JOHANNESBURG.

Wednesday, July 31.

Hon. Sir CHARLES PARSONS, O.M., K.C.B., F.R.S.—*Recent Progress in Steam Turbine Plant.*

The paper briefly describes the early history of the steam turbine in South Africa from the beginning of the century and contemporary with notable advances in turbine construction in England. Reference is made to the influence of the industrial

application, and consequent expansion, of electric supply upon the development of South Africa.

Modern developments in steam turbine design have been in the direction of increased output per unit, and increased fuel economy with higher steam pressures and temperatures, regenerative heating of the feed water, air pre-heaters and economisers, and the use of re-superheated steam after partial expansion.

The maximum blade annulus for a given speed of revolution has increased about ninefold during the past twenty years, and the output in rather greater ratio than this; at 1,500 revolutions an efficient turbine with a double-ended low-pressure stage can now be made with an output of 100,000 kw., and by arranging triple low-pressure stages in a tandem cylinder turbine 150,000 kw. can be obtained from a single unit.

Modern improvements in the design of surface condensers are in the direction of greater attention to the distribution of the steam among the tubes with the object of obtaining high vacuum, hot condensate and air-free feed water.

The paper proceeds to discuss progress in high-speed alternator construction. The maximum output of such alternators for a given rate of revolution has increased nearly fourfold during the last decade. For instance, at 3,000 r.p.m. the increase is from about 10,000 kw. to 40,000 kw. The largest alternator output at 1,500 r.p.m. obtainable at present is about 150,000 kw., coinciding with the maximum obtainable from a steam turbine at the same speed.

For alternators of large output the author advocates direct generation at higher voltages, such as 33,000 instead of the 6,000–11,000 volts usual at the present day, and gives arguments in support of higher voltages.

A section of the paper is devoted to the subject of the strength and reliability of large steel forgings for turbine shafts and alternator rotors. A new method of casting ingots is described, employing a mould of which the horizontal dimensions are greater than the vertical, the top and sides being maintained hot, so that the metal is cooled from the bottom upwards with more or less horizontal planes of solidification. This obviates the structural weaknesses incidental to the usual method, and enables ingots of the largest size to be cast with substantially uniform composition.

Photographs of etched central sections of two ingots, one cast by the usual method and one cast by the new method are shown for comparison.

The paper then turns to a brief discussion of recent progress in marine turbine installations, describing the latest arrangement of geared turbines with improvements in economy obtained as the result of higher pressures and temperatures, and giving a table of record fuel consumptions obtained from recent oil-fuel-burning steamships.

In conclusion, figures are given indicating the progress of high-pressure and high-temperature marine installations built or under construction in the Navy and the Merchant Service, following the pioneer experiment with the Clyde River steamer *King George V*.

Mr. BERNARD PRICE.—*Compressed Air Supply on the Rand.*

Prof. G. A. WATERMEYER and Mr. S. N. HOFFENBERG.—*A R sumé of Mining Operations on the Rand.*

Thursday, August 1.

Presidential Address by Prof. F. C. LEA on *Science and Engineering*.
(See p. 138.)

ELECTRICAL PROBLEMS :—

(a) Mr. C. H. MERZ.—*The National Scheme for Electricity Supply in Great Britain.*

After a brief historical survey of the development of electrical distribution and the extension of areas covered by supply undertakings, the paper deals with the reasons which led to the appointment of the Weir Committee in 1925. Previous experience having shown the need for compulsory powers if the interconnection of the various generating stations and networks of the country was to be brought about, the

Electricity Act of 1926, embodying the principal recommendations of the Weir Committee, contained such powers. The Act set up the Central Electricity Board, and defines its functions in relation to the Electricity Commissioners. It provides for laying down a national transmission and interconnecting system, and that the Central Electricity Board should be responsible for practically all generation by authorised undertakers in Great Britain, though not itself ordinarily acting as a producer. The Act further provides for the selection of those generating stations which are to be retained in operation, arranging for the interconnection of these selected stations and for the gradual standardisation of frequency throughout the country. Some particulars are given of the financial arrangements and of the economies which may be expected from the establishment of such a system. A map is given of the proposed system and of the various sections in which it is gradually being built up.

The paper goes on to describe the special technical details of the system both as regards the 132 kv. overhead lines, towers, insulators and transformers, and also refers to the subsidiary networks at lower voltage which form an important part of the complete scheme.

After a reference to wayleaves the author deals with the reasons which led to the establishment of a national system and the technical results which it may be expected to have upon electricity supply in the country. A reference is then made to the influence which the cheapening and spread of electric power supply is likely to have upon the distribution of industries and population, and to the effects which its general adoption for industrial and domestic purposes would have on the atmospheric conditions of large towns.

In conclusion, the author suggests that public opinion has now reached a stage when the appropriate authorities should adopt a more definite policy for a reduction in the amount of fuel burnt in densely populated areas and for a diminution in the number of domestic fires burning ordinary coal.

(b) Prof. E. W. MARCHANT.—*Limits of the Economical Transmission of Electrical Energy.*

Comparison is first made between the cost of supplying electrical energy from a super station built near a coal mine, using electrical transmission to the centre of distribution, with the cost of supply from a super station built near the centre of distribution and provided with coal by rail transport. When the coal mine is 20 miles from the centre of distribution it is shown that, in England, with stations of about 100,000 kw. the electrical transmission of energy by overhead lines similar to the 'grid' costs the same as the transport of coal by rail, when the coal consumption is 1·4 lb. per unit. With a smaller coal consumption per unit the electrical transmission would become more expensive, and for larger coal consumption per unit it is relatively less expensive.

The effect of difference in the distance of the coal mine from the centre of distribution is next discussed, and with a fuel consumption of 1·5 lb. per unit it is shown that the electrical method is cheaper than rail transport if the distance exceeds 15 miles. The longer the distance the greater the saving due to electrical transmission.

The influence of load factor is dealt with, and it is shown that improving load factor renders the electrical method of transmitting energy relatively cheaper.

In the last section of the paper comparison is made between the cost of generating electrical energy in hydroelectric stations and steam stations. For a station of about 100,000 kw. and with a 31 per cent. load factor at the centre of distribution, 600 miles away, it is estimated that an expenditure of about £80 per kilowatt is permissible at the hydroelectric station for economical transmission.

The permissible capital expenditure will be increased with improving load factor.

(c) Prof. O. R. RANDALL.—*An Investigation into certain Properties of Insulating Materials using Solid Contacts.*

Friday, August 2.

DISCUSSION ON ROADS.

Joint Discussion with Section I (q.v.) on *Problems connected with Deep-mine Ventilation.*

Reports of Committees on :—

- (a) *Earth Pressures.*
- (b) *Electrical Terms and Definitions.*
- (c) *Stresses in Overstrained Materials.*

SECTION H.—ANTHROPOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 428.)

CAPE TOWN.

Tuesday, July 23.

Prof. H. J. FLEURE.—*Racial Drifts in Africa and Europe.*

An attempt was made to promote exchange of views between workers in Africa and Europe. The important discoveries of Mr. Leakey's expedition to Kenya furnish many data supplementary to those of Professor Reek. The correlation of the pluvial periods in East Africa with glacial and post-glacial phases of climate in Europe is probably soundly based, but there is need to remember the important pluvial period observed in Mesopotamia and probably correlated with the Gschnitz Stadium in Europe. It may well be that this rather than an earlier stage is to be correlated with Mr. Leakey's third pluvial period, accompanied as he says by pottery which is associated with an Aurignacian type of culture but degenerates. With such a scheme of correlation Mr. Leakey's finds can be interpreted as indications of southward drifts. He has found markedly hypsistenocephalic leptorhine skulls, with cranial indices of about 70 or less and nasal indices under 50, and some have marked supraciliaries. Aurignacian skulls and later upper Palæolithic skulls in Europe are in several cases hypsistenocephalic, the Combe Capelle skull being a notable example, while several others from Predmost are important; the Combe Capelle skull, with marked supraciliaries, has a nasal index of 53.

The finding of large hypsistenocephalic skulls with strong supraciliaries in ancient graves in South Africa, as described by Dr. Broom, is interesting here. While several have broad noses, Dr. Broom gives one with nasal index 53, and one with nasal index 54.3. Mr. Leakey also has a case of an extremely large skull of index about 76 with the height considerably less than the breadth, a possible analogue on the one hand of the Cro Magnon skull and on the other of the Boskop skull. Like the Cro Magnon skull, Mr. Leakey's specimen is leptorhine.

Pigmy or Bushman types are not as yet described for ancient Kenya, but their distribution suggests that they are possibly a still older drift of mankind. They have been said to have left traces in Europe, *e.g.* at Schweizersbild, and it has been supposed that the hair as represented on the 'Willendorf Venus' is spiral hair. This is speculative. The idea of drifts of short ulotrichous types through Africa and S.E. Asia, with possible reduction of size in unfavourable surroundings, offers at least a useful hypothesis, and if we add the hypothesis that these drifts were early ones, we are enabled to think of these types as influencing subsequent drifts, *e.g.* those of the hypsistenocephalic types.

It may be that close correlation of types of skull with types of culture in Africa, *e.g.* the attempt to find a Hottentot physical type and so on, may be just as misleading as the old habit, now largely given up, of trying to group all the Aurignacian skulls in Europe under the name of the Cro Magnon race.

Prof. M. R. DRENNAN.—*Some Skulls recently discovered in South Africa.*

Mr. G. R. CARLINE.—*The Horizontal Narrow-band Loom in Africa.*

In parts of West and East Africa a horizontal treadle loom is used for weaving narrow bands of silk or cotton. The essential features of a fully-developed loom are present; that is, it has a reed and two or more heddles worked by the feet, but its

framework is varied and mainly very crude and elementary, being either a simple tripod support from which to hang the heddles or an elementary frame. It is this latter part of the loom that this paper is concerned with. The distribution of this loom is from Senegal to Nigeria in the west, and Kenya to Egypt in the east, and the suggestion in this paper is that it was introduced into Africa via Arabia.

Miss M. A. MURRAY.—*The Witch-cult in Modern Times.*

The pagan religion of ancient Europe. The Mother Goddess. The Horned God. The sacrifice by fire (a) of a human being, (b) of animals. The organisation of the ancient religion and its apparent effect on modern beliefs. Modern instances of the survival of the old religion.

Dr. W. V. EISELEN.—*The Sacred Fire of the Ba Pedi.*

Mr. H. STAYT.—*Divining Bowls from the Ba Venda.*

Wednesday, July 24.

M. L'ABBÉ BREUIL.—*The Eastern Palæolithic Art of Spain.*

Mr. R. U. SAYCE.—*An Indian Fire-walking Ceremony in Natal.*

Father W. A. NORTON.—*Native Lore Among the Basuto.* (Taken as read.)

Thursday, July 25.

Joint Discussion with Section F (q.v.) on *The Economic Competition between Advanced and Backward Peoples.*

Prof. R. RUGGLES GATES.—*Racial Crossing.*

The prevalence of inter-racial crossing throughout historical and prehistoric times is pointed out, and various examples are discussed. The need for the application of genetical methods in the analysis of racial crosses is emphasised, as well as the difficulties in their use with mankind. The importance of segregation in racial crosses is considered, and the significance of crossing in the production of new racial types.

Segregation as a means of racial analysis is considered in relation to the author's observations on Eskimos×Whites and Indians×Whites in Canada, and crosses between Indians, negroes and Portuguese in South America. Various other racial crosses are discussed, and the effect of the endocrine glands as an intermediate inheritance mechanism is considered. The conclusion is reached that segregation in racial crosses probably does not differ essentially from the well-recognised segregation which occurs in the inheritance of unit abnormalities, such as albinism, brachydactyly or epicanthus.

There are, however, certain differences between racial characters and abnormalities as regards inheritance. The former are apparently never sex-linked, and on the other hand there appear to be multiple factors for such racial characters as skin colour and eye colour.

Mr. P. W. LAIDLER.—*Native Pottery of South Africa.* (Taken as read.)

Friday, July 26.

Archæological Excursion to Pretoria and district.

JOHANNESBURG.

Wednesday, July 31.

Mr. L. S. B. LEAKEY.—*An Outline of the Stone Age in East Africa.*Mr. C. VAN RIET LOWE.—*Archæology of Sheppard Island with Addendum on Associated Fauna.*Prof. RAYMOND A. DART.—*Mammoths and other Fossil Elephants of the Transvaal.*

An exhibition will be arranged of mammoth and other elephant teeth secured from the Vaal River gravels and from other sites in the Transvaal.

The mammoth teeth form a four-stage evolutionary series from (a) four Pliocene types, e.g. *Archidiskodon subplanifrons* Osborn through (b) two advancing types, e.g. *Archidiskodon broomi* Osborn and (c) two penultimate types, e.g. *A. transvaalensis* Dart to (d) an ultimate hypsidont type, e.g. *A. Lanekomi* (sp. nov.) Dart.

In addition, three new primitive Pilgrimid types will be announced as well as a Loxodont from the Pilandsberg, ancestral to the modern African elephant, and a fossil modern African elephant from a depth of 17 feet in the Steelpoort River Valley.

Dr. L. FROBENIUS.—*Investigations in Southern Rhodesia.*

Thursday, August 1.

Presidential Address by Mr. H. BALFOUR, F.R.S., on *South Africa's Contribution to Prehistoric Archæology.* (See p. 153.)

Rev. NEVILLE JONES, Mr. J. HEWITT.

Mr. A. L. ARMSTRONG.—*Excavations at Bambata Cave, Matoppo Hills.*

Friday, August 2.

Miss G. CATON-THOMPSON.—*Excavations in the Rhodesian Ruins.*

In accordance with the wish of the Council of the British Association to undertake a fresh inquiry into the ruins of Zimbabwe, 'or any monument or monuments of the kind in Rhodesia which seem most likely to reveal the character, date and source of culture of their builders,' excavations have been carried out at various sites from April to September 1929. Detailed plans and sections have been made of unpublished ruins.

The main work has been concentrated at Zimbabwe. The Maund ruins in the Valley of Ruins provided undisturbed ground which was horizontally cleared over a considerable area down to virgin soil. The stratification was well defined, and showed that the objects from the oldest stratum, beneath granite-cement floors contemporary with the walls, resemble those known to be of Bantu origin. The site seems to have been re-adapted by later occupants (whose material culture differed little from that of the original inhabitants), who raised the floor level, burying or cutting away the old granite-cement pavements.

Test excavations were next transferred to the north-west slope of the Zimbabwe Acropolis hill. These touched bedrock at 18 and 24 feet respectively. The midden deposit of the old Acropolis dwellers was located at the base of these shafts, and yielded imported glass beads, native iron, sherds and pottery phalli. The terracing system, with massive retaining walls, which is a feature of the Acropolis hill, is found to belong to the latest local phase of building activities.

In order to test the possibility that an older and different culture might be associated with the Elliptical Temple, extensive trenches were cut to bedrock (1) outside the girdle wall; (2) in an adjacent set of buildings named the Mauch Ruins; and (3) a tunnel was driven, with the assistance of a mining engineer, vertically

beneath the Conical Tower itself from side to side, exposing the foundations of the structure, and enabled examination of the undisturbed deposits upon which they rest in an area 18 feet \times 4 feet \times 6 feet.

The result of these additional excavations confirmed the evidence, already supplied by the Maund and Acropolis work, for Bantu origin, probably not prior to the tenth century A.D.

About 180 miles N.E. of Zimbabwe, on the watershed of the Sabi and Inyazitsa rivers, three ruins were examined, Matindere, Mshosho and Chiwona. The last-named had been reported by the Native Department as lately as November 1928. Matindere is an elliptical building with a decorated girdle wall, and interior divisional walls. A peculiarity is the fact that its numerous original doorways have all, at some subsequent period, been closed by granite walling. The deposits are very shallow; bedrock was reached at about 2 feet. The granite outcrop upon which this ruin lies clearly shows the places where the building stone had been procured.

Mshosho, about 9 miles distant, is a typical hill-top fortress kraal, with tiers of fine defensive walls now rapidly collapsing. Its midden deposits were sieved and trenches cut on the main central platform, and in the rock passage through which the building is approached.

Chiwona is also a kopje site, where the huge masses of natural granite which top the hill have been skilfully incorporated into the building plan, as on the Zimbabwe Acropolis. Test trenches were cut to bedrock and the midden deposit explored.

The objects collected from these three sites in the Sabi Reserve differ little from those from Zimbabwe. A good quantity of glass beads were found in each. Those from Chiwona resemble the oldest series (judged on stratigraphical grounds) from Zimbabwe: Matindere, richest in quantity and poorest in variety, may be judged, on the evidence of their resemblance to the beads from Dhlo-Dhlo, to be of later date. Pottery shows local variations.

Another interesting ruin, Chibvumani, in the Bikita-Devuli district, was explored during a week in August. Ruinous walls cover an extensive area. Later re-adaptation of the site on lines similar to those noticed in the Maund ruins has also taken place here. The objects recovered correspond to those from the other ruins investigated.

Dhlo-Dhlo in Matabeleland was visited at the end of the season. Excavations were carried down to bedrock at 13 feet 6 inches in the enclosure examined by Dr. MacIver in 1905. The contents of a burnt hut provided an important group of native pottery associated with a Ming bowl and a glass bottle—probably Arab. The walls of this enclosure are certainly not earlier than this hut.

In no case has an excavation been abandoned, or an inference drawn, until bedrock has been reached; and particular attention has been given to the stratification in relation to buildings and walls.

The main conclusions are that the ruins are of native Bantu origin and that the building of the structures dates from a period between the tenth and sixteenth centuries A.D.

Dr. P. WAGNER.—*Exhibition of Map showing the Distribution of pre-European Mining in the Transvaal and Southern Rhodesia.*

Dr. P. WAGNER.—*Further Notes on Bronze Smelting from a Smelter in the Waterberg Transvaal.*

Miss WILMAN.—*Bushman Rock Engravings.*

Prof. RAYMOND DART.—*The Taungs Skull.*

The skull found at Taungs in November 1924 and described in *Nature*, February 1925, will be exhibited, and a summary will be given of the anatomical peculiarities upon which its zoological position rests.

Dr. R. BROOM.—*The Springbok Skeleton.*

Mr. J. H. S. GEAR.—*Cranial Form in the Native Races of Southern Africa.*

The skull-form in a series of Bush and Bantu peoples has been investigated, the system adopted being that of Sergi as modified by Frassetto.

Both these races are predominantly long-headed or Dolichocephalic, but evidence of admixture at some period with an Asiatic element is brought out, when characteristically broad-headed or Brachycephalic skulls occur in our unselected collection.

The form of the Bush skull is in the majority of cases Chamæ-pentagonoid, i.e. the typical skull is angular in vertical outline and of low altitude.

The Bantu cranial form is evidently of a more complex nature, as the greatest number of skulls are equally dispersed in the Ovoid and Ellipsoid classes, the altitude being higher than that of the Bush, viz. Orthocephalic.

A comparison of the Bush and Bantu types offers evidence in support of the idea that the pre-Bantu stock possessed Hypsicephalic (high-vaulted) skulls with an ellipsoidal outline, and that advancing from the north they ousted the Bush tribes into the south and south-western territories.

Admixture of the two races probably led to the production of the intermediate hybrid types found, which retain the characters of both Bush and pre-Bantu stock.

A map illustrating the skull-form distribution in the three main divisions was drawn up.

Dr. GORDON D. LAING and Mr. J. H. S. GEAR.—*A further Report on the Strandlooper Skulls found at Zitzikama.*

Eight skulls and one skeleton, found by Mr. Fitzsimons at a depth of 15 feet in a cave at Zitzikama, are described in detail and compared. This examination shows the skulls to form a mixed group, in which features of two distinct types occur variously combined. Further proof is thus supplied to a theory, previously advanced in a preliminary report (Laing, 1924) that the collection shows evidences of hybridisation. The elements present in the fusion are shown to be pure Bush (San), as exemplified by the skull Za 2 on the one hand, and an even more primitive type Za 3 on the other. This latter type has many close similarities to the Boskop Skull, and throughout the series features occur which warrant the conclusion that this more primitive stock was of the Boskop race.

Mr. L. H. WELLS.—*Fossil Bushmen from the Zuurborg.*

An open burial site in the Zuurborg, South-east Cape Province, excavated by Mr. Fitzsimons, yielded human skeletal remains at two different levels. The lower stratum of burials was about 7 feet, the upper about 4 feet below the ground level. The burials of the upper stratum had apparently been made from a former ground surface $2\frac{1}{2}$ feet below the existing surface.

The remains, especially those of the lower stratum, were completely mineralised, and were associated with stone and bone implements and ornaments. These have been described by Mr. Fitzsimons, and appear to belong to the Wilton culture (Late Stone Age).

The skulls found at this site display close affinities with modern Bushman skulls, but are of somewhat greater capacity, and one individual possesses Australoid features. The mandibles are of typical Bushman type. The bones of the lower extremity, on the contrary, are remarkably Neanderthaloid in character.

This fossil find provides unequivocal evidence of great antiquity for the Bushman race and culture in South Africa.

Mr. L. H. WELLS.—*The Skeleton of the Foot in the Bantu and the Bushman.*

The bones of the foot have been studied in a large series of Bantu and Bushman skeletons belonging to the collections of the Department of Anatomy, University of the Witwatersrand, Johannesburg, and the Macgregor Memorial Museum, Kimberley.

The results show that the Bushman foot is distinguished by a large number of special features, the majority of which are primitive. The architecture of the foot as a whole is similar to that of Neanderthal man.

The Bantu foot is much more similar to that of the European, although many individuals possess Bushman features, apparently as a result of Bush hybridisation.

Sexual differences are strongly marked in the Bantu, but are not recognisable in the Bushman foot.

Mr. L. H. WELLS.—*Variations in the Muscles of the Bantu Foot.*

A series of forty-four feet of adult Bantu, dissected in the Department of Anatomy, University of the Witwatersrand, Johannesburg, presented a very large number of muscular anomalies.

Almost all of these are explicable on a phylogenetic basis, the majority being conditions normally present either in the Simiidae or in the Cercopithecidae, while a few are best explained by comparison with conditions found in the Insectivora.

The flexor digitorum brevis is by far the most variable muscle in the Bantu foot, more than half of the total number of anomalies being found in this one muscle.

The conclusion is warranted that the musculature of the Bantu foot is less stable, and more prone to reversionary changes, than that of the European.

MR. J. GILLMAN.—*The Bush, Bantu and European Sacra.*

An investigation of the Bush, Bantu and European sacra of the skeletons in the collection of the Anatomy department, University of the Witwatersrand, demonstrates that the Bantu and Bush have certain distinctive features by means of which they may be distinguished from each other and from the European. Further, finer details in structure reveal that there are definite sex differences in the make up of the sacra of the South African races.

(a) *Racial*.—In the Bantu there is a strong tendency for a six-vertebral, and in the Bush for a four-vertebral, sacrum to predominate.

The absolute straight length of the sacrum is greatest in the Bantu and smallest in the Bush; the reduction in breadth between the second and third vertebræ is relatively as great in the Bantu as in the European, but in the Bush it is relatively greater than either of these two races; the absolute straight breadth is greatest in the European and smallest in the Bush; the maximum breadth of the base is greatest in the European and least in the Bush.

There is a distinct morphological difference between the spines of the Bush and Bantu and European; especially is this noticeable in the first and in the last two spines.

The European sacrum is hyper- or homo-basal, the Bantu male is hypobasal, and the female is homo- or hyper-basal; the Bush female is hyperbasal and the male hypobasal.

(b) *Sexual*.—The superior aspect of the ala of the sacrum in the European is a plane flat surface. In the Bantu male it is divided into two plane surfaces, namely, a larger antero-superior triangular area and a smaller posterior quadrangular surface. In the male Bush the superior aspect of the sacrum is smaller and has almost the same features as the Bantu. The female Bush presents the same characters as the Bantu female, but in the Bush these characters are more exaggerated.

The morphology of the *facies auricularis* may be employed to determine both race and sex of a sacrum. In the male Bush and Bantu the auricular surface extends on to the dorsum of the sacrum; in the female, with few exceptions, it does not. The area of this surface is greatest in the Bantu and smallest in the Bush. The number of pieces of the sacrum included in the *facies auricularis* varies in the three races. There is a slight sexual difference in the Bush. There is a difference in shape of the auricular surface and in the curve of male and female Bush and male and female Bantu.

Further, racial and sexual differences are to be found in (a) variation in the development of the mammillary processes (b) the structure of the sacro-iliac joint.

(c) *Non-Bantu Types*.—Firstly, there are a number of Bantu sacra which exhibit a number of non-Bantu characters repeating those of the Boskopoid sacrum found at Zitzikama. Secondly, the auricular surface of some of the Bantu sacra shows a striking similarity to the same surface ascribed by Pycraft to Rhodesian Man. Thirdly, the extreme hypobasality present in some of the Bantu, and the type of auricular surface associated with that basality, is closely akin to that of the human sacrum from loess at Honan described by Matsumoto (1915).

DR. LEWIS R. SHORE.—*A Report on the Spinous Processes of the Cervical Vertebrae in the Native Races of South Africa.*

A survey has been made of the spinous processes of the cervical vertebrae in a series of 94 human skeletons, including 11 Europeans, 68 Bantus, 12 Bushmen, and 3 presumed Euraficans.

It appears that bifurcate cervical spinous processes account for about 65 per cent. in Europeans, 18 per cent. in Bantus, and about 4 per cent. of the total numbers of vertebrae numbered 3 to 7.

Considering that the first vertebra is spineless in all three races, with very few exceptions, the second has special features which demand individual attention, and that the seventh has a spinous process with features constant in all three races, the inquiry can be limited to vertebrae numbered 3 to 6.

After this deduction the proportions of bifurcate cervical spinous processes are, European about 81 per cent., Bantu about 14 per cent., Bushmen less than 5 per cent.

The non-bifurcate cervical spinous processes of the South African native races exhibit wide variations of size and form.

Four types are recognised to which the names pedunculate, cleft, simple and rudimentary are given.

No very striking differences are found in the proportions in which these types of cervical spinous process occur in the Bantu and the Bushman.

Differentiation of Bantu and Bushman cervical vertebrae is impossible by consideration of only the morphological characters of the spinous processes. The diminutive size and slender build of the Bushman bones is the best distinguishing feature.

Heteromorphism of the cervical spinous processes is found in the Bushman, even after skeletons are most carefully selected in order to obtain the purest unmixed forms.

For this purpose two criteria were applied to the Bushman skeletons, *viz.*: size and build, and the characteristic skull form.

It is inferred that heteromorphism of the cervical spinous processes is the rule even in pure Bushman stock, and that there is no type of cervical spinous process characteristic of the Bushman.

The same inferences are maintained, *a fortiori*, for the Bantu race.

The spinous process of the axis is considered separately.

The bifurcate character was found in 6 out of 9 specimens of axis in Europeans, in 12 out of 64 Bantus and in 1 out of 11 Bushmen. Much variation of form was found in the Bantu and Bushman axis.

Bifurcate cervical spinous processes in the Bantu resemble those of Mediterranean rather than those of Nordic strains of the Caucasian race. It is suggested that these cervical spinous processes in the Bantu race may be the outcome of mingling with North African peoples on the East coast of Africa.

The great variation of size and form of the cervical spinous processes in both South African native races seems to indicate a phase of retrograde evolution.

The main variants of the cervical spinous processes can be recognised in their counterparts in lower animal forms.

Thus, the pedunculate type is common in the anthropoid apes, the simple type in the monkeys, but the rudimentary type is sub-primate.

No inferences as to the tribe of a Bantu skeleton can be made from the characters of the cervical spinous processes.

Mr. J. H. S. GEAR.—*The Fossil Baboons from Taungs.*

Fifteen specimens, mainly skulls and endocranial casts, were examined. These specimens, which are the remains of baboons, are all completely fossilised by the infiltration of limestone. They were obtained from the Buxton Lime Works near Taungs. By taking into consideration the state of the teeth and sutures of the skull and certain skeletal growth changes, it has been possible to determine the age and sex of most of the specimens. In a relatively large number of natural endocranial casts of which two are almost perfect in the preservation of the brain form, the distinctness of the sulcal pattern is striking.

This investigation shows that in the material there are included two species of baboon. The skulls of both, as compared with *Papio porcarius*, are relatively small, and do not exhibit the high degree of specialisation seen in the latter type.

All the endocranial casts belong to the one species which has been called *Papio Africanus*. The brain of this fossil species, as revealed by the endocranial casts, was in its form, relative development of the lobes, and in the nature of its sulcal pattern, of a lower order than that of the modern South African baboon.

The teeth closely resemble those of *Papio porcarius*, though minor differences are observed.

It is evident from the study of the material that these fossil species did not belong to the modern baboon species of *Papio porcarius*, but to species which have since disappeared as living species from the South African fauna.

In its lack of specialisation *Papio Africanus* conforms to a type such as would be anticipated in an ancestral form, and it appears likely that *Papio porcarius* is a descendant of this fossil species.

Mr. F. P. MENNELL.—*The Position in which the Broken Hill Skull was found.*

Prof. L. CIPRIANI.—*The Batonga of Northern Rhodesia.*

Prof. L. H. MAINGARD.—*South African Linguistics.*

Mr. B. H. DICKE.—*Language and Customs of Natives in the North Transvaal.*

SECTION I.—PHYSIOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 429.)

CAPE TOWN.

Tuesday, July 23.

Joint Meeting (Sections D, I) on *Experimental Zoology*. Communications:—

- (a) Prof. W. A. JOLLY.—*Lymph Hearts in Toads.*
- (b) Prof. L. T. HOGBEN and Mr. D. SLOME.—*The Chromatic Function in *Xenopus Lævis*.*
- (c) Prof. L. T. HOGBEN and Mr. C. GORDON.—*The Electrical Conductivity of Animal Tissues.*
- (d) Mr. A. ZOOND and Mrs. ENID HOGBEN.—*The Localisation of the Respirator Function in Invertebrates.*
- (e) Mr. T. SCHRIRE.—*Autogamy in Bacteria.*

The question of variation in bacilli was discussed. Mention was made of various types of colonies met with in one organism. It was suggested that the variations in these organisms' characters may be governed by some Mendelian law. The characters of the colonies were described.

Wednesday, July 24.

Messrs. L. MIRVISH, G. SACHS, and T. SCHRIRE.—*Studies in the Mechanism of Bile Secretion.*

Experiments have been done on the Calcium content of gall-bladder bile, as well as bile draining from the common bile duct with the cystic duct tied. The results appear to indicate that Calcium is excreted by the liver through the hepatic bile in quite appreciable quantities, and that there are indications that Calcium is, to a certain extent, selectively re-absorbed in the gall-bladder.

Similar work on cholesterol is being undertaken.

Mr. J. PRYDE.—*The Present State of Chaos in Muscle Chemistry.*

Dr. J. S. HALDANE, F.R.S.—*The Dissociation of Oxy-hæmoglobin.*

Presidential Address by Prof. W. E. DIXON, F.R.S., on *Physiology the Basis of Treatment*. (See p. 164.)

Afternoon.

Demonstration (with Section D, *q.v.*) in Prof. HOGBEN'S Experimental Laboratory.

Thursday, July 25.

Joint Discussion (Sections D, I, K) on *The Nature of Life* (General the Rt. Hon. J. C. SMUTS, P.C. ; Dr. J. S. HALDANE, F.R.S. ; Prof. L. T. HOGBEN ; Prof. H. WILDON CARR ; Prof. R. F. A. HOERNLE ; Prof. G. BARGER, F.R.S. ; Prof. E. C. C. BALY, C.B.E., F.R.S. ; Sir DANIEL HALL, K.C.B., F.R.S. ; Prof. A. S. EDDINGTON, F.R.S.).

Friday, July 26.

Discussion (Sections B, I) on *Vitamins*.—Prof. E. MELLANBY, F.R.S. ; Prof. A. HARDEN, F.R.S., &c.

Dr. H. ZWARENSTEIN.—*Nitrogenous Excretion in Xenopus Lævis*.

The urine of *Xenopus* (the South African clawed frog) was collected every twenty-four hours. Urea, ammonia, creatine, creatinine and traces of uric acid were found to be present. 100 c.c. of urine contain 70 mg. urea, 28 mg. ammonia, 2.5 mg. creatine, and 0.20 mg. creatinine at 20° C. Each frog excretes on an average 5 c.c. of urine per day. Decreasing the temperature to 5° C. causes an increase of about 100 per cent. in both creatine and creatinine.

Previous attempts by various investigators to demonstrate the presence of either creatine or creatinine in amphibian urine have been entirely negative. The amount of creatine in the blood was 1.40 mg. per 100 c.c., but the presence of creatinine therein was not definitely established.

Dr. L. P. BOSMAN.—*Carbohydrate Tolerance in Xenopus Lævis*.

JOHANNESBURG.

Wednesday, July 31.

Prof. A. D. STAMMERS.—*Some Influences of Light on Physiological Functions*.

Mr. W. B. OSBORN.—*Preliminary Observations to Determine the Ultra-Violet Content of South African Sunlight*.

Mr. L. E. HERTSLET.—*The High-Veld Climate from the Heliation Angle*.

Dr. T. M. MAVROGORDATO and Dr. J. S. HALDANE, F.R.S.—*The Effects of Dust Inhalation*.

Thursday, August 1.

Dr. R. S. CREED.—*Some Recent Work on Reflex Action*.

Mr. E. N. WILLMER.—*The Nutrition of Cells growing in vitro*.

Mrs. M. MELLANBY.—*Some Factors controlling the Structure of the Teeth and their Susceptibility to Caries*.

Two new methods of studying problems connected with the teeth, especially in relation to their susceptibility to caries, have been adopted in the researches to be described.

(1) The study of the conditions which result in perfectly calcified teeth regularly arranged in well-developed jaws.

(2) Methods for increasing the resistance of the living teeth to harmful influences, such as attrition and caries, after eruption.

The careful examination, both macroscopical and microscopical, of large numbers of teeth, especially of deciduous teeth of children, has demonstrated a definite relationship between the structure—the calcification—of teeth and their liability to decay; the worse the structure the greater the susceptibility. Now these investigations have shown that the majority of children in the British Isles (and probably in other countries also, although much less material is at present available for investigation in the latter) possess poorly calcified teeth. About 80 per cent. of the deciduous teeth, not 2 to 3 per cent. as has been usually stated, were found to be defective or hypoplastic in structure. The incisors were much better calcified and less susceptible to caries than the molars. It is, therefore, obviously important to ensure good calcification of the developing teeth. In puppies and other animals perfect and imperfect teeth can be produced at will by slight variations in the diet, and as far as our present limited knowledge goes, these same variations in diet affect the structure of children's teeth also.

The two main factors influencing dental structure have been shown to be Vitamin D which aids calcification, and some substance in cereals which interferes with this process. The effect of ultra-violet radiations, also conducive to good dentition, is now known to be due to the production in the tissues of Vitamin D from its precursor ergosterol. A minimum of calcium and phosphorus is, of course, essential, but this minimum varies with the amount of Vitamin D in the diet, and cannot be stated as an absolute quantity. Neither Vitamin C nor Vitamins B₁ and B₂ have any specific effect upon the calcification of teeth in puppies.

Although there is a definite relationship between structure and caries, teeth perfect in structure sometimes become carious, whereas defectively calcified teeth may remain free from the disease. It has been shown experimentally that the resistance of teeth to external harmful stimuli can be controlled by diet independently of the original structure and that some of the same factors of diet which influence the development of teeth also affect their resistance.

Controlled investigations on children, based on the experimental work on animals already mentioned, show that the initiation and spread of dental caries can be greatly reduced by increasing the intake of vitamin D and reducing that of cereals, and especially of oatmeal.

Calcification of the deciduous teeth starts while the infant is in utero; it is therefore essential that the mother during pregnancy and lactation should have a sufficient supply of the substances necessary for good calcification, partly to ensure an adequate supply of these substances to the child, and partly that she herself may not go short of them in releasing her own supplies to the developing embryo, and thus become more liable to dental decay.

The English diet, especially that of the poorer classes, undoubtedly contains a deficiency of fat-soluble vitamins which are associated with the more expensive foods such as eggs, milk and butter, whereas cereals, which interfere with calcification processes, form the bulk of the diet, for they are comparatively cheap and easily transported. The decrease in breast-feeding and the consequent rearing of infants on cereal concoctions must also tend to result in defectively calcified teeth.

Although much remains to be learnt as to the aetiology of dental caries, there seems to be little doubt that if more vitamin D and less cereals were included in our diet the structure of our teeth would be very much improved and their susceptibility to caries would be greatly diminished.

Dr. S. MONCKTON COPEMAN, F.R.S.—*Cancer and Diet.*

When the location of the disease is not such as to prevent the taking of sufficient nutriment it has been found possible, by the adoption of certain dietetic measures, to secure, in many instances, definite prolongation of life as judged by observation of many similar cases, together with such comparative, or even complete, alleviation of pain as alone could render any such extension of life worth while.

The dietary in question was first suggested at the Cambridge Meeting of the British Medical Association in 1920, and was the subject of a paper at the Liverpool Meeting of the British Association in 1923. Since then it has been tested in a considerable number of cases in various infirmaries and elsewhere; while in order to

obtain information as to its effect on the normal individual doing a fair amount of mental and physical work, the writer adopted it over a period of about twenty months. The dietary, which has been somewhat modified and simplified as experience dictated, is based on the idea of restricting, as far as possible, the ingestion of foodstuffs rich in fat-soluble vitamins of *animal* origin. In practice this means the disuse of meat (except pork in various forms, including ham, bacon, sausages, &c.), and of eggs, butter and cream, the necessary amount of vitamin being obtained mainly from vegetables, especially water-cress, and fruit. White fish of all kinds are allowed, so that the dietary is by no means a 'vegetarian' one only. Moreover, it can be completely satisfactory from the physiological point of view, and with the exercise of a little care may be made both sufficiently varied, and tempting to the appetite.

It might be thought that in a wasting disease such as cancer is apt to become in its later stages, a dietary depleted of what are commonly regarded as specially nutritive foods would prove insufficient to sustain life. But this suggestion is negated by the fact that patients on changing over to this dietary, provided that they are not practically moribund at the time, or that the course of the disease is not specially rapid, so far from losing flesh still further, almost invariably *increase* in weight. After some weeks or months a state of equilibrium usually tends to become established, which may persist until such time as dissolution is imminent, when a sudden and rapid fall in weight not infrequently supervenes.

This method of treatment would seem also to be specially indicated after operation, with the object of preventing, if possible, recurrence of the disease.

Investigations on a somewhat extensive scale, concerned with the dietary and cancer statistics of various 'enclosed' monastic communities at home and abroad, have been carried out, extending over a series of years, with the object of obtaining reliable information bearing on the subject-matter of the paper.

Prof. FRANCIS E. LLOYD.—*The Feeding Habits of Vampyrella Lateritia.*

The feeding habits of *Vampyrella lateritia* as at present understood have already been set forth by the author (Papers *Mich. Acad. Sci. Arts and Letters* 7, 395–416, 1926). The present purpose is to review the work of Gobi (*Scripta Botanica Horti Universitatis Petrogradensis*, Fasc. 16, 1925), whose views have not been made generally available. Aside from points of agreement as to preliminary movements, Gobi held that the attack of the animal on the food plant (*Spirogyra* or *Mougeotia* spp.) consisted, after attachment, of the formation of a food-receptive vacuole formed from sap taken up from the attacked cell by plasmolysis induced by the animal. Penard held that suction was exerted. It will be argued that the cytolytic action of the animal on the cell wall of the food plant affords an explanation in harmony with all the observed facts. That true suction occurs after the breaking of the food cell seems undeniable, and evidence will be offered to support the view that the form of the food receptive vacuole (in the present sense) is such as to enable suction to be exerted by the animal. Illustrated by lantern slides and motion pictures.

Friday, August 2.

Joint Discussion (Sections G, I) on *Problems connected with Deep-mine Ventilation* (Dr. J. S. HALDANE, F.R.S.; Dr. A. MAVROGORDATO; Dr. A. J. ORENSTEIN; Dr. H. PIROW; Dr. J. H. DOBSON; Mr. M. O. TILLARD; Mr. E. C. RANSON; Mr. E. C. POLKINGHORNE, and Mr. H. MITCHELL).

Dr. J. S. HALDANE, F.R.S.—The Reports by Messrs. Tillard and Ranson on temperature conditions in the Village Deep Mine, and by Messrs. Mavrogordato and Pirow on the physiological effects of these conditions, give a clear picture of the temperature difficulties met with in very deep mining on the Rand. No mine in Great Britain is more than about half the depth now reached on the Rand, but the conditions which I have myself met with are sometimes even more formidable as regards both dry-bulb and wet-bulb temperatures. This is partly because the rock-temperature in Great Britain usually rises about 1° F. for every sixty or seventy feet below surface, as compared with 1° for about 220 feet on the Rand; but largely also because oxidation of coal, pyrites, and timber contributes greatly to the rise of temperature, which does not seem to be the case in Rand mines. I shall first refer

to recent advances in knowledge as to physiological acclimatisation and voluntary adaptation to heat, and to the indirect effects of excessive loss of salt in sweating, and then pass to the main subject of this paper, of which the following is an outline.

The great trouble met with from heat in deep Rand mines, in spite of acclimatisation and good ventilation, raises a question which can only be discussed partially in to-day's meeting. In order to avoid dust inhalation in the Rand mines the air is at present kept everywhere practically saturated. The precautions taken against dry dust have been extraordinarily successful in reducing the risk of silicosis; but if we could avoid the saturated air without increasing the risk of silicosis we could greatly diminish the temperature troubles, and thus make still deeper mining of low-grade ore a practicable proposition.

We could, I believe, avoid the silicosis risk with drier air if we could add to the quartzite dust another kind of dust with the property of rendering the silica harmless. In metalliferous mines elsewhere than on the Rand the effects of the quartz dust seem to be, in many cases, neutralised by natural means in this way; and in British coal mines the stone dust, which is either present naturally or added in order to prevent coal-dust explosions, does not produce miners' phthisis though it contains about 35 per cent. of quartz and nearly 60 per cent. of total silica.

Whether it is possible to avoid silicosis by dry methods will be discussed at another meeting, but meanwhile we may consider the advantages which could be gained by dry methods as regards the effects of heat on men. What might be pictured is that the air in the shafts, inclines, and splits should, by avoidance of most of the evaporation, be kept at a mean temperature not below the natural rock-temperature, but about equal to it or even above it. This would naturally result from adiabatic compression, since the rate of rise of temperature by adiabatic compression with depth is very distinctly greater than the rate of rise of rock-temperature on the Rand. Thus the air would reach the working places with its cooling power through evaporation of sweat almost unimpaired; and if stopes could also be left dry it would pass upward to higher workings with cooling power still great and would cool by adiabatic expansion as it rose, instead of being to a large extent prevented from doing so by condensation. The available air could therefore be concentrated on the deeper workings, where it would be needed most.

With the rock-temperature and air-temperature at 90° to 100° in the deeper workings we might have a wet-bulb temperature of at least 20° lower, permitting much more work than at present. The cost of dusting with the neutralising dust would probably be small in relation to diminished costs in other directions; but in any case I think we ought to consider the great possible advantages. We are being beaten just now by the rock-temperature. If, as seems possible, we could make the rock cool the air rather than warm it, we should not, up to much greater depth, be greatly troubled by the heating from adiabatic compression. Possibly, also, rock-bursts might be diminished.

The advantages from dry air in British coal mines are very great, now that the dangers from coal-dust explosions have been to such a large extent overcome by stone dusting. One of these advantages is the abolition of risk from ankylostomiasis; and possibly the very low death rate from tuberculosis among coal miners is connected with the dry conditions.

Where, as in some Rand mines, the heavily timbered shafts and inclines must be kept wet, the air, if concentrated in the airways, would reach the bottom quite cool at depths at present reached, and its wet-bulb temperature would only rise to a quite moderate extent in the stopes, if they were kept dry.

SECTION J.—PSYCHOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 429.)

CAPE TOWN.

Tuesday, July 23.

Prof. R. W. WILCOCKS.—*On the Correlation between the Intelligence of Siblings.*

Mr. E. FARMER.—*A Psychological Study of Accident-proneness.*

Prof. G. DAWES HICKS.—*The Phenomena of so-called Fusion.*

By the 'blending' or 'coalescence' or 'fusion' of presentations there has been understood either (a) the synthesis or conjunction of heterogeneous contents—contents belonging to distinct types of sense-experience, or (b) such synthesis or combination as is supposed to be involved when the contents assumed to unite are homogeneous in character. These two kinds of result are essentially different.

(a) To this there corresponds exactly what Locke designated a 'complex idea'; and, so far as a title is needed for describing what is meant, no better can be found than 'complexes' or 'complications.' The sense-organs are stimulated in most cases together; indeed, we have no experience involving stimulation simply of one sense. From the outset, therefore, our sense-experience is complex. But we do not start with *recognition* of this complexity as a fact; nor do we start with the apprehension of isolated contents and recognition of their conjunction. The essential process in sense-apprehension is, roughly speaking, the gradual recognition of qualitative differences *and*, correlatively, the establishment of more or less firm conjunctions among presentations belonging to different orders, as also amongst those belonging to different species of the same order. Here we find, in fact, the germs of the process to which the name of 'association' is usually given. Those sense-presentations which are grouped together, and which are gradually recognised as forming wholes, have their elements associated. There is, it seems to me, no real ground for the law that is called that of 'similarity'; the only associative principle is that of contiguity of whole and part. Now, so far as the first class of phenomena to which the name of 'fusion' has been applied is concerned, these are explicable along the lines indicated. It is not to be assumed that there are originally experiences of separate qualities, and that these become blended into a whole in which they are no longer distinguishable. On the contrary, there is first the experience of an undifferentiated whole, and gradually the conscious subject comes to recognise the different qualities combined in this whole. Illustrations: 'tonal fusion,' the facts of binocular vision, so-called fusion of retinal images, &c. In none of these cases is there any such thing as a blending together into one fused totality of a number of separate presentations.

(b) If there is such a thing as a fusion of presentations at all, it would be of the kind to which the Herbartian psychologists and, in his earlier writings, Wundt, applied the term—namely, a synthesis or blending of contents homogeneous in character. According to the view in question, the formation of definite, sharply defined contents comes about by a sort of superposition of contents already more or less definite and precise in character. For such a view there is no real psychological foundation. We do not start with the awareness of definite contents, which are subsequently revived and superimposed upon new contents indistinguishably like them. An act of apprehending is essentially an act of discriminating, and the conditions under which discrimination can be carried out are originally supplied in such small quantity that the first apprehended contents are necessarily the least definite and precise. It is due to the fact that apprehension of what we call the 'same' content occurs in conjunction with the most varied surroundings that there is rendered possible recognition in what is apprehended of qualities, aspects, relations, which at first did not form part of it. Accordingly, the increasing definiteness of a presentation does not come about from anything that can rightly be called a fusion or blending of presentations. The results ascribed to such a process are not in truth explained thereby, and they can readily find explanation in terms which are not thus out of keeping with all that we know of the mental life.

Mr. J. G. TAYLOR.—*The Nature of Consciousness.*

Wednesday, July 24.

Joint Discussion with Section L on *Psychological Tests in Relation to Education and Vocational Guidance.*

Dr. SHEPHERD DAWSON.—Psychological tests have so far played no very important part in education in Great Britain. Their use has hardly passed the experimental stage. Practically the only tests that have proved useful are the intelligence tests. The others are little more than laboratory curiosities.

This is due partly to the difficulty of finding suitable tests and partly to failure to consider the essential purpose of a test. As every test aims at diagnosing capacity or natural mental endowment, and yet is obviously in itself a test of ability, *i.e.* of what the examinee can do at the time of the test, it is necessary to ask how a test of ability can become a test of capacity. There are several possibilities. First, if one could be certain that a test was new to all the examinees, one might assume that success at it was determined by natural capacity: but it is difficult, perhaps impossible, to find such tests. Again, the examinees might be given complete training and then tested. For practical purposes of prognosis, except where the training can be accomplished in a very short time, such a test would be useless, but it would be valuable for checking the results of other methods. Finally, the test might be of such a kind that it could be assumed that all the examinees had had equal training or equal opportunities of training. This is the principle on which the Binet tests have been constructed. The reliability of these methods will have to be compared by repeating the same tests on the same people at different chronological ages, and making a statistical analysis of the results, for only in this way can one find whether it is natural capacity, as distinct from acquired ability, that is being tested.

Some work has been done in this direction in regard to intelligence tests; it is very incomplete, but sufficient to produce the conviction that the intelligence quotient, which is commonly regarded as a measure of capacity, is approximately constant.

Although there is still very much to be done to put psychological tests on a scientific footing, their practical usefulness is beyond question: in this respect mental testing is like a good deal of medical practice, it provides a suitable opportunity for forming a fairly reliable opinion of an individual's potentialities. We can look hopefully toward the time when the diagnosis of children's capacities will form an essential part of our educational system, for the work of both teacher and pupil can be adequately judged only if one knows the latter's achievements.

Thursday, July 25.

Dr. VICTORIA HAZLITT.—*Children's Thinking: Some Experimental Results in relation to Recent Theories.*

Dr. MARGARET MACFARLANE.—*Training the Mentally Unfit.*

Mr. H. E. O. JAMES.—*Transfer of Training.*

Friday, July 26.

Presidential Address by Mr. F. C. BARTLETT, on *Experimental Method in Psychology*. (See p. 187.)

Prof. H. F. VERWOERD.—*A Contribution to the Experimental Investigation of Testimony.*

Dr. C. S. MYERS, C.B.E., F.R.S.—*A New Interpretation of Adaptation.*

JOHANNESBURG.

Wednesday, July 31.

Prof. E. EYBERS.—*The Bloemfontein Psycho-educational Clinic: a brief statement of its activities and findings.*

Mr. J. D. SUTHERLAND.—*Speed in Intelligence.*

The study of speed in the intelligent reaction has been suggested by Prof. E. G. Boring as the most likely mode of attack on the systematic investigation of the

nature of intelligence and 'its meaning in psychological and physiological terms.' The present paper reports the results of measurements of the speed of reactions of varied complexity of a small group of boys, the reactions ranging from reflex time as given in the patellar tendon reflex to speeds in the higher processes.

Miss MARGARET DRUMMOND.—*Magic and the Child.*

There are three modes of interpretation which may be applied by man to his environment: (a) magical (self-power); (b) supernatural (other-power); (c) rational (power through understanding or insight). Infantile experience necessitates the priority in time of (a). Mental progress consists in the gradual substitution of (b) and more particularly of (c) for (a), though few, if any, human beings eliminate (a) entirely. In times of stress reversions to (a) are common.

A specifically human power is the power of escape from reality—a power which is found at every level of intelligence, and is indeed necessary for the progress of thought. In such escapes (a) retains or regains dominance, unless the escape is made under the guidance of insight, in which case the results are brought back to the test of experience.

Innate differences probably exist in the force of the escape tendency. Unhappiness in reality produced by fear, lack of satisfaction, &c., will foster it, and favour complete divorce from reality.

The younger the child or the lower the intelligence the greater is the likelihood that (a) not (c) will govern the mental activity, and that the divorce from reality will be complete.

Many cases of primary mental defect, of delinquency, of educational retardation, may be due to arrest of mental progress from (a) to (c), an arrest rendered possible by the power to escape from reality.

Mental development takes place only under the stimulus of the environment, so that withdrawal from the influence of the environment must be a potent factor in mental retardation.

Illustrative cases.

Miss M. D. VERNON.—*Distractions in Reading.*

During the reading of letters, disconnected words and sentences, the liability to distraction by different kinds of visual obstructions interposed between the lines varied considerably for different individuals. Those in whom the tendency to fixate the obstructions was strongest and most variable were greatly affected by a number of subjective factors, of which the most important was the effort to arrange and organise their perceptions of the experimental material in accordance with previously formed patterns of language and thought. Apprehension of the content of the reading matter was much impaired by the connections and conflicts which arose between these organisations of meaning. But in reading sentences the motor reactions were directed and regulated by the deeply rooted motor habits formed in normal reading.

Other individuals who were less readily distracted by the visual obstructions were much more objective in their attitude. They paid less attention to the meaning and interest of the experimental material and more to the efficient execution of the necessary eye-movements.

Thursday, August 1.

Prof. T. M. FORSYTH.—*The Significance of Holism.*

Holism means the tendency to the origination and development of wholes or unities in nature or the universe generally.

As thus defined, holism is a principle or concept in the philosophy of science that claims to replace, or at least to supplement, that of mechanism.

According to the principle of mechanism, the essential character of even the most highly developed products of any natural process is expressed by showing them to be only very complex cases of the same kind of action and the same intrinsic qualities as are exhibited in lower or simpler occurrences. Or again, on this principle, any kind of whole or unity is nothing but the sum of its parts, the mechanical resultant of

elements or factors that remain without change in forming or effecting the total thing or occurrence.

This attitude is very largely justified both in principle and by results. Indeed, inasmuch as it is an inherent necessity of the analytic and quantitative aspect or character of scientific method to reduce things to their simplest elements and to view complex things and processes as formed out of these as their constituents, mechanism must retain its place as the chief, if not the only, principle of scientific procedure unless a method is forthcoming that conserves its truth and value while supplementing it by some other principle.

The question is not that of a division of spheres or levels of existence, some of which are capable of complete explanation on mechanical principles, while others are incapable of such explanation, and require the introduction of other principles. For there is no sphere that is not in any degree susceptible of the application to it of the terms and categories of mechanism.

Nevertheless, it is gradually coming to be recognised that this procedure gives only a partial explanation of *any* natural process. There is, in any complex process, a principle of synthesis involved, such that, instead of the whole being the mere sum of the parts and being explicable by the mere composition or combination of the parts, it is rather the case that the parts can only be explained by reference to the whole, since they are modified by their relation to it. If so, mechanism must be supplanted, or at least supplemented, by a mode of explanation that gives due regard to this.

This principle of wholeness or unity is exemplified in many different spheres of fact, *e.g.* in atomic structure, in chemical synthesis, in the life of an organism and even in the character of the single life-cell, in the processes of perception and volition, and also in so-called reflex action, in the development of personality and the attainment of social control.

Holism, then, signifies that everything in the universe is in some form or another, and in greater or less degree, potentially or actually, an organic whole; that as anything develops to a fuller realisation of its potentialities or a fuller perfection of its nature, it becomes more truly such a differentiated and yet unified whole; and that, by implication, the universe itself is an infinite organic whole.

This involves that nothing in nature can be explained merely as the result of preceding processes or anterior stages of development. The lower or simpler is the condition without which the appearance of the higher or more complex would be impossible; but the development to higher levels is possible at all only through the impulse to organic unity or synthesis under the controlling influence of the infinite whole.

Prof. H. WILDON CARR.—*Imagination and Reasoning.*

Dr. O. A. OESER.—*On the Interpretation of Psychological Experiments from a Typological Standpoint.*

Just as there is a reaction in education against a strict uniformization that has resulted in the 'standard child,' so in psychology to-day there is a reaction against the experimental procedure that results in uniformization and the 'standard subject.' But although a great number of theories of psychological types has been produced, few of them stand on a rigorous experimental basis like that of Jaensch and the Marburg School.

To achieve consistent results, it becomes necessary to separate subjects into groups, and to correlate the experiments on each group with other experiments on the same group. We can no longer take a mixed lot of subjects and hope to get standard results. The separation into groups has to be done by tests. These are evolved by studying individuals of some pronounced, possibly abnormal type, and tracing the structural peculiarities thus found into the broad field of normality. The question of attitude and instruction becomes of great importance, since an instruction may favour the normal reaction of one type and not of another, thus leading to erroneous interpretations of the results. This is well evident from tachistoscopic experiments on reading. The controversies that these raised have been solved by applying the structural typological method. This method also throws fresh light on the problem of attention, and the wider problems of the antitheses between idealistic and materialistic philosophies through a study of the modes of experience of different types.

Dr. M. L. FICK.—*Intelligence Tests Results of Coloured, Native (Zulu), Indian, and Poor White Children and their Social and Educational Implications.*

Friday, August 2.

Mr. R. J. BARTLETT.—*The Memory Value of Colour in Advertising.*

Ten advertisements in colour and the same advertisements in Black and White were shown in various pre-arranged order in automatic books to 5,000 visitors at the Advertising Exhibition held in London in 1927. The principal problem attacked was the relative value of colour and black and white when *all other things are equal*, and the method adopted was to exhibit black and white and coloured advertisements in a second book in identical position to those occupied by their equivalent coloured and black and white in the first book. In this way 2,500 reports on colour were balanced against 2,500 reports on equivalent black and white advertisements. Taking one hundred returns as a basis, it was found that the ratio of returns from colour to returns from black and white from 400 records from each of ten different sets of combinations of the advertisements varied from 54·3 : 45·7 to 49·0 : 51·0 with a mean value of 51·5 : 48·5. The difference though small is statistically significant, and the figures are very similar to those obtained by Nixon in America by an entirely different method. Small initial advantages are magnified greatly owing to the fact that so little time is given by the average man to advertisements, but it seems unlikely that the proved value of colour in advertising can be due to this small advantage alone. It is more probable that the 'pulling power of colour' is founded on a combination of this small initial advantage with other factors, and that one of these is the relative amount of coloured and black and white advertisements carried by the particular medium.

Accordingly, the various combinations of advertisements were arranged to attack the problem of the effect of the ratio of coloured to black and white advertisements on memory value. Combinations in which two, four, six and eight coloured advertisements appeared in the centre of a book with the outer leaves carrying black and white advertisements were balanced by similar advertisements with black and white central blocks.

The greatest difference between colour and black and white was obtained from single advertisements at the ends of blocks of eight of the contrasting advertisements.

The returns were equal with end blocks of four advertisements and central blocks of six, and in every other case colour had an advantage which increased as the number of coloured advertisements diminished. When books of all black and white were compared with books of all colour we approximated most closely to the conditions of Nixon's American experiment and obtained figures identical with his—52·5 : 47·5.

It follows that in the interest of the advertiser the coloured pages in a magazine should be limited, and that above a certain maximum, which would appear to be somewhere between one-quarter and one-third, colour ceases to be worth the extra cost, and that when coloured advertisements outnumber the black and white ones, it is more profitable to use black and white, and also that in the present state of the hoardings the use of black and white should pay handsomely.

Comparing the black and white returns from different combinations, it is found that in every case the total return from the black and white is greater than from the complete book of black and white, which would seem to indicate that the 'pulling power of colour' is not obtained at the expense of the black and white advertisements accompanying it, but that the advertising value of the whole is increased by the introduction of colour.

The experiments were arranged to cancel all effects of individual differences between the various advertisements, but it is possible by analysis to throw these individual differences into relief and then, among others, the following interesting results emerge :—

(a) Straight-forward realistic art secured considerably more returns than modernist art. The ratio being approximately two to one.

(b) Advertisements of known articles secured much better returns than those of unknown articles. The ratio again being about two to one.

(c) It is possible for good black and white work to secure better results than average colour work.

(d) An advertisement that is of little value when presented in black and white may be made highly efficient by the use of colour.

Dr. J. DREVER.—*A Hue-Discrimination Spectrometer.*

This instrument is a spectrometer which has been devised mainly for the determination of colour thresholds. It gives a uniform colour field, one half of which can be varied by means of deviating prisms, while the other half remains constant. The two fields can also be varied in brightness by means of sliding neutral glass wedges. In addition, there is an attachment for mixing colours, and in particular for giving the Rayleigh equation by mixing Lithium red and Thallium green so as to produce Sodium yellow.

Dr. MARY COLLINS.—*Individual Differences in Sensitivity to Red and Green.*

The investigation to be reported was carried out with Dr. Drever's Hue-Discrimination Spectrometer. The first part is concerned with the determination of thresholds; so far only those for lithium red and thallium green have been determined. It has been found there are considerable individual differences.

By means of a special arrangement, already described in Dr. Drever's paper, the mixture in the Rayleigh equation was determined for the same subjects. They were asked to equate a mixture of lithium red and thallium green to sodium yellow. This was also carried out with spectral colours on a colour mixer. The object of this experiment was to see if there was any correlation between the threshold results and variation in the Rayleigh equation, that is, whether a big deviation from the normal in the Rayleigh equation was accompanied by threshold values in red and green larger than the normal threshold values.

Mr. G. C. GRINDLEY.—*Experiments on the Functions of Rods and Cones in Vision.*

Mr. S. J. F. PHILPOTT.—*Apparent Periodicities in the Work Curve.*

It is not suggested that the curves to be shown are periodic in a strictly mathematical sense. A better description is wavelike or oscillatory, and it is quite possible that this is all we should expect normal work curves to be.

Apparent waves can be made manifest to the eye by appropriate methods of smoothing. Most of those first met with in this research seemed to be geometric. Thus, one little group of curves has crests at the 45th, 90th, 180th, 360th . . . seconds from zero time. These values are in G.P. with log increment $\cdot 3010$. Other log increments have been measured, ranging in value from $\cdot 0160$ to about $\cdot 6000$, these limits being determined by the nature of the curves used.

Occasionally, it appeared as though there were also waves of arithmetical nature, but most of the early curves seem to indicate that the geometric waves are dominant. On the other hand, work now in progress with more powerful methods of analysis, e.g. the method of serial correlations, shows that arithmetical periods or durations can be inferred much more frequently than one first supposed. The work is not yet complete, but it seems that curves based on one or two experiments will usually appear more geometric than arithmetic (there are cases where the converse happens), but that as more and more experiments are pooled, arithmetic durations become more and more obvious. The weaker curves are very variable, showing some possible geometric durations. Grand total curves tend to resemble one another, i.e. they approach a standard form. It is interesting therefore to note that, so far, the arithmetical durations (whether seen in weak or strong curves) all seem to have a duration lying between 55 and 60 seconds or simple fractions thereof (approximately 30, 20 or 15 seconds). The evidence strongly suggests that pooling results in an averaging of geometric elements with consequent clarification of the arithmetic element or elements.

The durations or periods of geometric waves are apparently neither general nor specific in the accepted sense. One cannot be sure when, or with what task or with what individual any particular length of wave will appear. We can conclude therefore that the geometric waves are due to some influence extrinsic to the task or the permanent characteristics of the subject. What those influences are one cannot

say. They may be of the environment, although it hardly seems likely from the available evidence. Or they may be subjective, such things as degree of interest, practice, fatigue, &c.

The arithmetical durations are so constant that one at once suspects them to be due to something in the environment. Again, however, there is a doubt. Control experiments show that they are just as strong, even when special precautions have been taken. Further research on this point is required.

There are then many puzzling features in the research. On the whole, however, it would appear that the work curve, as commonly produced, is far more definitely rhythmical than is usually supposed.

SECTION K.—BOTANY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 430.)

CAPE TOWN.

Tuesday, July 23.

Prof. R. S. ADAMSON.—*The Vegetation of the Cape Peninsula.*

Mr. R. D'O. GOOD.—*The Geography of the Genus Coriaria.*

Coriaria is the only genus in the *Coriariaceæ*, a family of polypetalous Dicotyledons of very uncertain affinity.

The genus is, geographically, almost unique, since it is found in no less than four widely separated parts of the world, *i.e.* Western Mediterranean; continental and insular Eastern Asia, New Zealand, New Guinea and parts of Polynesia; Western South America and Central America.

It can be divided into three quite distinct subgenera of which two (one monotypic) are confined to the two northern generic areas, and one is confined to the southern areas.

A number of fossils have been ascribed to *Coriaria*, but nearly all are merely detached leaves which may or may not belong to the genus. Of particular interest is a complete fossil branch with leaves and fruits from the Oligocene of Southern France, indistinguishable from a species now living in the Himalayas.

The present discontinuity *within* the northern and southern hemispheres can be attributed largely to the immediate or subsequent effects of the climatic changes culminating in the Pleistocene Glaciation. The discontinuity *between* the two hemispheres presents a difficult problem, involving the question of the point of origin of the genus and the directions in which extension of area has taken place especially across the tropics. Several theories can be made to explain the facts, but it is suggested that a modified theory of continental movement involves as little hypothesis as any other.

Mr. W. N. EDWARDS.—*Paradozopteris, an African Fossil Fern Stem.*

The genus *Paradozopteris* was instituted by Hirmer for a curious petrified stem from the Cretaceous of Egypt, which he had previously referred to *Osmundites* (?); it was still included in the *Osmundaceæ* and was described as consisting of a mass of leaf-traces, the stem stele being unknown.

A different interpretation is now proposed, and the vascular system is regarded as being a highly complex example of polycyclus, the supposed *Osmunda*-like leaf-traces being stem meristemes, more or less concentrically or spirally arranged.

The nearest approach to this structure among recent ferns is to be found in *Angiopteris*, and it is possible that the relationships of *Paradozopteris* may be with the *Marattiaceæ*. The genus is now also recorded from the Cretaceous of Darfur, on the evidence of specimens recently collected by Mr. G. V. Colchester, and the possibility of its connexion with the wide-spread Lower Cretaceous frond-genus *Weichselia* is discussed.

Prof. R. H. COMPTON.—*Features of Botanical Interest in the National Botanic Gardens.*

Afternoon.

Dr. MARGERY KNIGHT.—Lecture (semi-popular) on *Seaweeds, a Study of Adaptation and Opportunity.*

Wednesday, July 24.

Prof. J. H. PRIESTLEY.—*The Movement of Water and Solutes in the Tree* (in the Department of Forestry, for which see later pages).

A study of the seasonal activity of the cambium in the tree throws quite a new light upon the processes by which water is moved, in the early part of the growing season, from the trunk into the young shoots, and upon the manner in which organic solutes are transferred downwards in the tree towards the close of the growing season.

Prof. M. VICTORIN.—*Some Evidence of Evolution in the Flora of North-Eastern America.*

Evidences of evolution are seen in the presence of local endemics in definite parts of North-Eastern America. The origin of these endemics is ascribed to isolation, both geographical and physiological. Geographical isolation has been most effective: (a) by separation, lengthwise, of North America into two separate land masses during Cretaceous times; (b) by submergence of the North Atlantic land-bridge with Eurasia at the end of Tertiary times; (c) by glaciation.

Physiological isolation has produced endemics in North-Eastern America, chiefly in the case of estuarine plants.

Dr. A. S. HITCHCOCK.—*Grasses in relation to Man.*

Prof. FRANCIS E. LLOYD.—*The Mechanism of the Trap of Utricularia.*

It is now well established by the work of Merl and of Czaja that the trap of *Utricularia* is a self-setting mechanism, that the setting results from the expulsion of water by the walls, resulting in reduced pressure within entailing their collapse, and that this condition is normally sustained for long periods, during which no water enters. It is evident that the door or valve must be a very efficient mechanism. As to how this efficiency is attained, the prevailing view has been that the door edge rests with its outer aspect very firmly on the threshold (all observers except Brocher and Withycombe), or pressing outwardly against a ridge assisted by the curvatures of the walls (Brocher), or finally by pressing inwardly against the forwardly directed sides of the glandular cells clothing the upper surface of the threshold (Withycombe); but in all cases the explanation postulates the presence of mucilage (mucus) as a sealing substance.

It will be argued that Withycombe's idea, though not substantiated by his evidence, is correct, but that only the middle portion of the free edge of the door (Czaja) rests against the upper, but forwardly directed, surface of the pad, to the shape of which due attention must be directed. The lateral portions of the door traverse the pad in such fashion that there is a sharp re-entrant angle between door and pad, affording places which could not resist the water pressure without leaking were it not for some adequate means of stanching the flow. There is no mucus or mucilage as previously held. There is, however, a membrane, derived by exfoliation of the cuticle of the glandular cells of the pad, which becomes free inwardly and remains attached outwardly to form a second valve which completely seals the entrance by overlapping the door edge and the lateral folds. The extremely sudden operation of the door on touching the trigger hairs, and the water-tight character of the whole, is thus satisfactorily explained. The species studied is *U. gibba*.

Dr. WINIFRED E. BRENCHLEY.—*The Influence of Traces of Various Elements upon Plant Growth.*

The importance of traces of the rarer elements found in plants is gradually becoming apparent, as it is demonstrated that in certain cases they have a definite physiological function in relation to metabolism. Many elements are known to improve growth if presented in sufficiently small amounts, but it is now evident that minute traces of boron, manganese, zinc, &c., are as essential to the development of some plants as the major nutrients, phosphorus, potash and nitrogen. There is some evidence to indicate that the discrepant results obtained by various investigators may be due, partly at least, to environmental conditions such as variations in light intensity. Strong insolation often tends to increase the harmful effect of deficiency of certain elements, as is shown by the different degree of development of broad bean in water culture in dull spring and bright summer weather in the absence of boron, and by the chlorosis induced in peas when the iron is rendered less available for chlorophyll development by too bright sunlight at critical periods. Small doses of copper sulphate have been successfully used to raise crops on infertile peat in Florida, but English peats, both acid and alkaline, have so far failed to give a similar response with the same crop plants.

The exact physiological function of these essential traces of elements has not yet been fully determined. Manganese is assumed to be concerned with enzyme activity as it is a constituent of laccase, boron is associated with the development of meristematic tissues, and appears to be bound up with the calcium nutrition of the plant, and copper in some cases may be comparable to iron in plant economy. Claims have been made for the essential nature of traces of a considerable range of elements including iodine, fluorine, aluminium and zinc, but more investigation is needed to determine whether these are merely stimulating agents, or whether they play a definite part in the metabolism of certain plants, as has been shown with boron and manganese.

Afternoon.

Excursion to the National Botanic Garden, Kirstenbosch.

Thursday, July 25.

Joint Discussion with Sections D and I (q.v.) on *The Nature of Life.*

Miss A. V. DUTHIE.—*The Life-history and Morphology of Riccia purpurascens.*

Mrs. M. R. LEVYNS.—*The Problem of the Rhenoster Bush.*

Dr. ELIZABETH S. SEMMENS.—*Hydrolysis of Starch in the Living Plant.*

Starch in the mesophyll of a young and healthy leaf is shown to undergo hydrolysis after four or five hours' exposure to light polarised by a Nicol's prism or by reflection. On a leaf so exposed, after staining with iodine, a light patch is seen, corresponding in shape and position with the aperture of the Nicol.

Not only is starch so affected, but other highly organised substances, such as glucosides, can be broken down.

A deep crimson leaf of *Beta vulgaris*, exposed as above for six hours, after dipping in weak sulphuric acid, was soaked in amyl alcohol. Red drops of colouring matter dissolved out at the exposed area and a lighter patch was seen, showing that the anthocyanin had hydrolysed to anthocyanidin and had been dissolved by the amyl alcohol.

As the vertical light of the evening and morning sky is strongly polarised, this fact has an important bearing on plant metabolism.

To demonstrate this effect, patches of small leaves, such as 'Lucerne,' were exposed to the afternoon sky light from 4 to 6 p.m., but shielded from the setting sun. These

showed, on staining, less starch than similar patches covered during that interval, in spite of the fact that the latter had received two hours less bright daylight than the former. The starch was hydrolysed by the polarised sky light, for this effect was not seen in cloudy weather, when polarisation was feeble. Further evidence was also given of starch hydrolysis in the guard-cells of the stomata under similar conditions, thus confirming the description given by the writer in 1925.

Dr. A. B. WALKOM.—*A Comparison of Australian and South African Fossil Floras.*

Dr. H. HAMSHAW THOMAS.—*Is Phyllocladus a Relic of the Mesozoic Thinnfeldias?*

In the earlier part of the Mesozoic period plants bearing leaves of the type constituting the form-genus *Thinnfeldia* were important constituents of the vegetation of South Africa and of many other parts of the world. Very little is known of their nature and affinities, and they may not all have been of one kind. Several writers have linked them with the modern *Phyllocladus*, the curious conifer of New Zealand and other islands of the Western Pacific.

The author has studied the contents of a large deposit of leaves in the Jurassic rocks of Yorkshire, which are close to the typical *Thinnfeldias* in their general characters but differ somewhat in their stomatal structure. It seems impossible to regard these foliar structures as *phylloclades*. But with the leaves occurs a curious type of cone which can be linked to them with a considerable degree of certainty. This cone seems to have had a large verrucose fleshy axis in which numerous seeds were partially embedded at irregular intervals. The seeds were larger than those of *Phyllocladus*, but, like the *Podocarps* and other *Taxaceæ*, had an epidermis with numerous stomata. This structure seems more comparable with the ovulate strobilus of *Phyllocladus* than with any other plant, and it would appear that the suggested relationship cannot be disregarded.

The apparent existence of a plant with pinnate leaves and a strobilus and seeds referable to the *Taxaceæ* is most surprising.

Prof. J. H. NEETHLING.—*The Genetics of certain Characters in Wheat.*

Afternoon.

Excursion to Lion's Head.

Friday, July 26.

Discussion on *The Origin and Evolution of the South African Flora* (Dr. R. MARLOTH, Prof. BEWS, Prof. COMPTON, Dr. I. B. POLE EVANS, C.M.G.).¹

Dr. R. MARLOTH.—As an historical introduction to the vegetation, the physical conditions and the climate of Southern Africa we may quote Thunberg's drastic description (at the Cape, 1772 to 1775) of his experiences: 'Per dunas arenosas, rivos infidissimos, Carro aridissimas, campos undulatos, littora falsa, colles lapidosos, alpes altas, præcipitia montium, fruteta spinosa sylvasque inconditas pericula vitæ adii, feroces gentes et bruta prudenter elusi. Thule hujus australis gazas speciosas detegendi gratia lætus cucurri, sudavi et alsi.'

The region of the Cape flora has been designated by later authors in various ways.

¹Copies of a Guide to Botanical Survey Work are available to members through the kindness of the Director of the Botanical Survey of South Africa, and can be obtained from the Local Hon. Secretary, Section K, Cape Town.

Rehman (1880) and Engler (1882) applied the term 'South-western region' to the country as far east as Mosselbay. Drude (1887) used the term 'Evergreen scrub region' for the same area, and Schimper (1898) termed it 'Sclerophyllous Scrub Area.' The first author to treat the whole area from the Bokkeveld in the North-west to Van Stadens mountains on the south coast as one province out of the five into which he divided South Africa, was Bolus (1886), naming it the South-western region. Marloth (1908) emphasised the contrast shown by the flora of this area when compared with the remainder of South Africa by employing the term 'The Cape Floral Kingdom.' Pole-Evans (1920) calls it 'the coast veld' and 'the South-west veld,' and in another publication (1922) the 'Cape Region,' while Bews (1925) employs the term 'South-western region,' and speaks of its vegetation as the 'Mountain and South-western vegetation,' suggesting the local term 'Fijnbos' as a general designation.

Prof. J. W. Bews.—In Natal and Zululand all the various elements of the South African flora are well represented. The hygrophilous bush of the coast-belt is more or less an outlier of the tropical flora. The trees composing it are relatively primitive types according to all theories of phylogeny, and this view is confirmed by the fact that the wood of one of the commonest, *Eugenia* (*Syzygium*) *cordata* has been described from the Cretaceous beds of the coast. They are also relatively inefficient and unspecialised physiologically; they carry out their various functional activities at a relatively slow and uniform rate throughout the year. Numerous lianes, a smaller number of epiphytes and a few forest herbs are more advanced in response to the effects of the living environment (biota). All have close tropical affinities.

The temperate South African flora in Natal is best represented on the mountain ranges, but isolated species have penetrated through the tropical and sub-tropical elements. On the whole the evidence that is being accumulated points to this southern temperate flora being more ancient, in many respects, than the northern. This applies *e.g.* to the temperate tribes among the grasses. The South African temperate flora connects with that of the Mediterranean region, and that in turn with the North temperate flora of Europe and Asia.

Response to a dry (winter) resting season has been responsible for the maximum amount of differentiation in the sub-tropical flora of the whole eastern side of South Africa, as well as the central, northern and north-western regions. Natal is peculiarly well situated for studying all the steps in the process. In the dry river valleys conditions are found approaching very closely to central Karroo conditions, and the flora is similar. This xerophytic flora is from every standpoint the most highly evolved in South Africa. Probably in future the most fruitful line of research will be in the study of the details of its physiological behaviour.

Prof. R. H. COMPTON.—*The Karroo*.—The Karroo is bounded north and east by a 'northern' or Central African flora, south and west by a 'southern' or circum-antarctic flora. The Karroo flora is highly derivative, a miscellaneous assortment of northern and southern types selected through adaptability to aridity and grazing. Both factors act by destroying subærial growths, and the flora accordingly shows features of storage, unpalatableness and regeneration.

Characteristic southern families (Proteaceæ, Ericaceæ, &c.), typically 'hard-wooded' shrubs lacking regenerative powers, though in close contact with the Karroo, do not enter it. Some families, mainly southern in South Africa, can, however, penetrate the Karroo by reason of tendencies to geophily and succulence (Crassulaceæ, Geraniaceæ, Iridaceæ).

The woody flora is largely derived from families with a wide northern and southern distribution (Compositæ, Leguminosæ, Solanaceæ, Sterculiaceæ, Anacardiaceæ, Rubiaceæ, &c.). Most species are both distasteful to animals and drought resistant through chemical means, the few edible species having great regenerative powers.

The opportunist ephemerals belong to widely distributed genera; other herbaceous elements (Gramineæ) being outliers of northern or southern genera.

Geophily, exemplifying storage and grazing-survival, is most conspicuous in bulbous monocotyledons, and Liliaceæ and Amaryllidaceæ are well represented in the Karroo; but many dicotyledonous genera have also taken advantage of geophilous tendencies to colonise Karroo areas.

Succulents, combining storage with distastefulness, are the most distinctive Karroo elements. Stem-succulent Euphorbiaceæ and Asclepiadaceæ are mainly northern, leaf-succulent Aizoaceæ and Crassulaceæ have strong southern affinities, other groups being more general geographically.

Karroo stream-beds contain arboreal extensions of northern tree-veld.

Dr. I. B. POLE EVANS, C.M.G.—North of the Orange River, as far as latitude 22°, and west of the Drakensberg escarpment, six types of vegetation are found—desert, semi-desert, desert-grassland transition, steppe, savannah and temperate rain forests.

The characteristic plants of the desert are : *Eragrostis spinosa*, *Aristida brevifolia*, *Acanthosicyos horrida*, *Welwitschia mirabilis*, *Sarcocaulon Burmanni*, *Pachypodium namaquanum*, *Aloe dichotoma*, *Euphorbia gregaria* and *Tamarix articulata*; of the semi-desert : *Aristida obtusa*, *Aristida brevifolia*, *Mesembryanthemum spinosum*, *Salsola Zeyheri*, *Zygophyllum Morgsana*, *Rhigozum trichotomum*, *Catophractes Alexandri*, *Parkinsonia africana* and *Acacia giraffæ*; of the desert-grassland transition : *Aristida ciliata*, *Schmidtia kalahariensis*, *Schmidtia bulbosa*, *Antheophora pubescens*, *Danthonia suffrutescens*, *Aristida uniplumis*, *Eragrostis pallens*, *Monechma incana*, *Citrullus vulgaris* and *Acacia hæmatoxylon*; of the steppe : *Themeda triandra*, *Andropogon hirtiflora*, *A. cerasiæformis*, *A. schirensis*, *A. nardus validus*, *A. excavatus* and *Microchloa altera*; of the savannah : (in the north) *Acacia pallens*, *Combretum porphyrolepis*, *Adansonia digitata*, *Copaifera mopane* and *Terminalia prunioides*, (in the south) *Burkea africana*, *Terminalia sericea*, *Peltophorum africanum*, *Dombeya densiflora*, *Faurea saligna* and *Mimusops Zeyheri*; and of the forest : *Podocarpus latifolius*, *P. Henkelii*, *P. falcatus*, *Curtisia jagina*, *Xymalos monospora* and *Anthocleista zambesiaca*.

Although only part of this area lies within the tropics, tropical African forms are to be found over the whole; in fact, the outstanding point about the area as a whole is the strongly marked invasion of the South African flora by the tropical African flora.

The flora of this area shows affinities also with the floras of tropical America, tropical Asia and Madagascar.

The endemic tropical African flora is represented in this area by such genera as : *Welwitschia*, *Encephalartos*, *Urelytrum*, *Perotis*, *Phæoptilon*, *Portulacaria*, *Xymalos*, *Burkea*, *Cordyla*, *Kirkia*, *Triaspis*, *Kissenia*, *Rhigozum* and *Catophractes*. The Asiatic relationship is shown by the following genera : *Dinebra*, *Gloriosa*, *Sansevieria*, *Lannea*, *Salvadora*, *Caralluma*, *Sessamum*, *Pygeum*, *Balanites* and *Commiphora*; while the Madagascar affinity is shown by : *Hyphæne*, *Kniphofia*, *Aloe*, *Faurea*, *Hexalobus*, *Sphedannocarpus*, *Catha*, *Peddiea*, *Kigelia* and *Harpagophytum*; and the American affinities by *Olyra*, *Ctenium*, *Antheophora*, *Tristachya*, *Raphia*, *Anona*, *Ocotea*, *Copaifera* and *Hermannia*.

Miss E. R. SAUNDERS.—*A Chapter in Floral Evolution.*

The hitherto accepted view of the constitution of the pistil is based on the supposition that all carpels are of one uniform type, each representing a leaf folded lengthwise and inwards, bearing the ovules on the conjoined margins.

This conception leaves many facts unexplained. It has, moreover, recently been shown to be beset with difficulties and to be at variance with numerous structural features which point to a different explanation, as indicated below.

This later view recognises the same processes of evolution among carpellary leaves as are met with among all other plant members, viz. differentiation of form going hand in hand with division of labour. In other words the outcome of these processes here, as elsewhere, is *not uniformity but polymorphism*.

There is overwhelming evidence that two main types of carpel have been evolved : (a) the valve or hollow type which is more or less extended laterally and, if fertile, bears the ovules either singly or in a single row on either margin; (b) the consolidated type which, if fertile, produces ovules either singly or in from one to several rows on each flank of the midrib. The consolidated type may show an appreciable lateral extension (semi-solid or pseudo-valve form), or it may consist merely of a column or radial plate of tissue (solid form).

In ovaries of one carpel (e.g. *Anemone*, *Clematis*, *Potentilla*, *Rosa*, *Alisma*) the carpel is of valve form.

In ovaries of more than one carpel two kinds of carpel are usually present. Among exceptions to this generalisation may be cited *Nandina domestica* (Berberidaceæ) (G2, rarely 3, of the valve type), *Fritillaria imperialis* (G3+3, all semi-solid). In the typical case one carpel type is fertile, the other sterile. Either the fertile or the sterile type, or both, may develop stigmas. When both carpel types are stigma-bearing the two sets of stigmas may be alike (occasional flowers in *Eschscholzia*, *Reseda*) or dissimilar (*Fumaria*, *Parolinia*, *Aphyllanthes*, *Aspidistra*, *Paepalanthus*). In *Aphyllanthes* both sets are functional, but as a rule this is not the case.

In many instances carpel polymorphism appears to have arisen in association with considerable reduction in carpel number, as in Rosaceæ (*Potentilla-Rosa* types v. other sections of the family), Phytolaccaceæ (*Phytolacca-Ercilla* types v. Rivineæ), Ranunculaceæ (*Anemone-Clematis* types v. *Nigella*), *Alisma* v. *Butomus*.

In some cases reduction has resulted in the utilisation of persisting elements of those members which are suppressed in the construction of those which survive; these latter might therefore be said to arise by a process akin to synthesis.

Transition from one carpel form to another may occur in allied forms (*Capsella Bursa-pastoris* and *C. Heegeri*, *Triglochin maritimum* and *T. palustris*, certain species of *Oxalis*, the median carpel pair in 2-valved and 4-valved ovaries of the Cruciferae.

The conception of carpel polymorphism as outlined above

(a) Satisfactorily explains the whole series of anomalies in the pistil of the Cruciferae.

(b) Accounts for the commissural stigma in general.

(c) Affords a rational explanation of obdiplostemony.

(d) Throws a new light on parietal, free-central, superficial and axile placentation, and on loculicidal dehiscence.

(e) Shows that the anomalies of the solitary terminal carpel, the gynobasic and the supernumerary style and the false septum are not realities.

(f) Renders intelligible the infertility of the female organ in the male flowers of many diclinous species.

Dr. R. MARLOTH.—*The Nomenclature and Chemistry of Euphorbia virosa*.

Dr. T. R. SIM.—*New South African Trees and Shrubs*.

Prof. P. A. VAN DER BYL.—*Descriptions of Some Previously Unnamed South African Fungi*.

Mr. R. DAVIES.—*The Growth and Development of Peaches*.

Dr. and Mrs. I. B. POLE EVANS.—*Scenes of South African Vegetation*.

Dr. L. VERWOERD and Mr. B. J. DIPPENAAR.—*Descriptions of New and of Unrecorded Species of South African Fungi*.

Afternoon.

Excursion to Muizenberg.

Saturday, July 27.

Excursion to Table Mountain.

JOHANNESBURG.

Wednesday, July 31.

Prof. C. E. MOSS.—*Vegetation of South Africa, with Special Reference to the Witwatersrand District*.

Miss D. WEINTROUB.—*The Aquatic and Sub-aquatic Vegetation and Flora of the Witwatersrand District*.

The area investigated extends from Florida, nine miles west of Johannesburg, to Brakpan, twenty-three miles east of this city.

The sheets of water may be classified as follows:—

(1) *Artificial dams*, usually in connection with the gold mines, and, as a rule, of little botanical interest.

(2) *Semi-natural lakes*, made by the artificial damming up of natural streams. Florida Lake is the best known. Reed swamps occur, with the following plants

locally dominant: *Typha australis* (very closely allied to *T. latifolia* and *T. angustifolia*), *Phragmites communis* (apparently the form of southern Europe), *Scirpus macrocarpus* (looking like *S. lacustris*), and *Cyperus fastigiatus*. Of plants with floating leaves, *Limnanthemum thunbergianum* (allied to *L. peltatum*) is abundant in Florida Lake. Submerged plants occur, such as *Potamogeton javanicus* (with a few floating leaves), and *P. badius* (allied to *P. pusillus*), *P. sp. nov.* The margin is rich in marsh species, including *Juncus effusus*, *J. spp.*, *Ranunculus sardous* (agg.), *R. meyeri* var. *transvaalensis*, *Nasturtium officinale*, and *Epilobium villosum* (aff. *A. hirsutum*). *Spergularia* (aff. *S. marginata*) sp. n. occurs on the margin of Geduld Lake.

(3) *Pans*, or shallow depressions whose origin is in dispute. The pans are frequently dry in winter. However, 'Lake' Chrissie, in the eastern Transvaal, is a pan containing permanent water. The pans have a typical and characteristic marginal flora, with *Spergularia* sp. n. (aff. *S. salina*), *L. essertia* sp. n., *Cuscuta* sp. n., and others. *Lemna* 'minor,' *L. gibba*, and *Wollfia arhiza* occur locally in the pans of the East Rand. *Potamogeton pectinatus* var. and *Zannichellia repens* occur in Brakpan. *Potamogeton livingstonii* is abundant in Lake Chrissie and some adjacent pans. The pans have a rich plankton, consisting chiefly of Copepods and Diatoms: *Volvox* (a large species), and *Hydrodictyon* (probably the recently described *H. indicum*) occur in Reitfontein pan. The pans have no streams flowing out of them, and consequently their mineral content is high, becoming almost supersaturated as the dry season approaches. Incrustations of salts are of common occurrence on the receding margins of the pans, as the waters are drying up.

(4) *Streams* and their backwaters. *Batrachospermum* sp. occurs in several of the streams. The backwaters have the same flora as the lakes; and the stream-banks yield the same plants as the margins of the lakes.

Mrs. M. Moss.—*A Revision of the Genus Gnidia.*

In the course of this investigation, it has been found necessary to take the broad view of *Gnidia*, as given in the *Pflanzenfamilien*. As understood by the present author, *Gnidia* includes *Arthrosolen*, *Lasiosiphon*, and even *Englerodaphne*. Thus defined, *Gnidia* contains nearly 150 species which range from Cape Town, through the whole of South Africa (including the Karroo), Madagascar, central Africa, to India. These species form a natural genus, and show such close intergradings that no definite or constant characters have been found which warrant any subdivision into smaller genera.

Taxonomically, the genus is at present in a very confused state. This is partly due to insufficient study of the type-specimens of the older species of Linnæus, Linn. fil., Thunberg, and Lamarck. It is also partly due to the making of new genera and new species on the study of insufficient material. Sharp distinctions which appear to hold when one or very few specimens are studied are often found not to hold when a more extended study is made. The group is undoubtedly plastic; and its members appear to hybridise rather freely. There need be no doubt as to the common origin of all the species.

Certain evolutionary tendencies are apparent, but are not constant or important enough to be of generic value.

The revision has entailed a study (including work on comparative anatomy) of such a large mass of material that probably the results will be published in three parts: (1) the species of the Transvaal and the Orange Free State, (2) those of the Cape of Good Hope and Natal, and (3) those of Madagascar, Central Africa, and India.

Prof. C. E. Moss.—*The Genus Anthericum in South Africa.*

Miss D. M. WELSH.—*The Anatomy of African Species of Salicornia and Allied Genera.*

The late Dr. Ethel de Fraine investigated the anatomy of the glassworts of western Europe. The present work is on similar lines, but applies to the glassworts of Africa. In each case, the work was done in connection with taxonomic work on the *Salicorniæ* by Professor Moss.

The genera investigated by Dr. de Fraine were *Halocnemum*, *Arthrocnemum*, and *Salicornia*. To these, the present work adds the alternate-leaved *Haloepelis*.

The African species investigated comprise *Salicornia* sp. n. A, *S. perrieri*,

Arthrocnemum glaucum, *A. fruticosum*, *A. sp. n. B*, *A. indicum*, *A. sp. n. C*, *A. nom. nov.* D (= *S. pachystachyum* Black non Bunge), *A. sp. n. E*, *A. sp. n. F*, *A. sp. n. G*, *A. sp. n. H*, *A. sp. n. I*, *A. sp. n. K*, *A. sp. n. L*, *A. comb. nov. K* (= *S. perenne* var. *radicans*), *A. sp. n. L*, *Halocnemum strobilaceum*, *H. sp. n. M*, and *Halopeplis amplexicaule*.

The present work supports Dr. de Fraine's main conclusion that the succulent exoskeleton of the glassworts is foliar in origin.

Details of the distribution of 'spiral cells' and 'steroids' in the foliar sheath, and endodermis of the above species will be given. These details confirm Dr. de Fraine's work in so far as the species common to western Europe and Africa are concerned.

Mr. E. R. ROUX.—*Growth Forms of Marsilia macrocarpa*.

Afternoon.

Excursion to Klipriversberg.

Thursday, August 1.

Presidential Address by Prof. A. C. SEWARD, F.R.S., on *Botanical Records of the Rocks*. (See p. 199.)

Dr. I. B. POLE EVANS, C.M.G.—*The Botanical Survey of South Africa*.

Prof. J. W. BEWS and Mr. J. E. VAN DER PLANK.—*Response to the Resting Season in South African Plants*.

The tropical hygrophilous element in the South African flora shows no well-marked responses to seasonal variations. The temperate element of the south-west and mountain regions remains, for the most part, evergreen, and there is therefore in this case as well no definite period of complete rest. In the large sub-tropical element, on the other hand, the dry winter resting period has undoubtedly been responsible, in a general way, for the high degree of differentiation reached. While the methods of comparative morphology do throw considerable light on the problems involved, in recent years more attention has been paid to the basic physiological processes.

Colloidal carbohydrates (both pentosan and hexosan) increase with aridity. Different sides even of the same tree may differ widely in chemical composition. In perennials storage carbohydrates are often drawn upon to a much less extent than is commonly supposed for the purpose of flower and seed production.

The imbibition capacity and general functional significance of plant colloids in connection with arid conditions and seasonal responses require further investigation.

Prof. R. R. GATES.—*Chromosome Linkage*.

Linkages of chromosomes during the prophase of the reduction division, which therefore limit the free distribution of chromosome pairs in meiosis, have now been discovered in several plant genera, including *Oenothera*, *Godetia*, *Rumex*, *Aucuba* and *Tradescantia*.

In *Oenothera*, where they have been most extensively studied, they appear to be clearly related to the genetic behaviour, forming the basis of much of the widespread genetic linkage in *Oenothera* hybrids. A striking feature of these linkages is that they remain constant, the F_2 showing the same arrangement as the F_1 . Comparison of the linkage in a considerable number of the F_1 hybrids with that of the parents has so far failed to disclose any general rule of relationship. The linkages in the hybrid may be the same as those of either parent or may differ from both.

In mutations the linkage is usually less than in the parent form, but in gene mutations, such as *Oenothera rubricalyx*, there is no change in the chromosome linkages.

It appears probable that many of the wild species of *Oenothera* are persistent species-hybrids which breed true on account of the chromosome linkage, and that this is the condition under which the evolution of the genus *Oenothera* has taken

place. The linkages arise either as a result of pairing between non-homologous chromosomes or possibly from an interchange of segments between chromosomes. The study of these linkages is thus throwing a further intensive light on the process of mutation and its relation to evolution.

Dr. C. E. B. BREMEKAMP.—*The Taxonomic Importance of the Mode of Branching in Vascular Plants.*

As early as 1837 Brongniart showed that axillary shoots are found only in the Spermatophytes, that the branches of the Equisetales are not axillary, but inter-axillary, and that the ramification of the Lycopodiales and Filicales is of the dichotomous type. Subsequent taxonomists, however, did not pay much attention to the mode of branching. Velenovsky, to whom the various types were well known, lessened the value of the differences by a rather unfortunate endeavour to show that the ramification of the Equisetales is only a modified dichotomy. He was probably led astray by the preconceived opinion that the Equisetales, as an integral part of the Pteridophytes, should have the same type of branching as the other classes belonging to this group. Further development of our knowledge of the vascular plants has shown, however, that the characters by which the Pteridophytes and the Spermatophytes were originally separated are not of such paramount importance as they seemed to be, and that the differences between the various classes brought together in the group of the Pteridophytes were rather underrated; it is only conservatism which maintains at the present moment the Pteridophytes as a separate group.

The importance of the dichotomous type of branching as a special character of the Filicales, Lycopodiales, Ophioglossales and Hydropterides, was somewhat obscured by Schoute's discovery of the occurrence of this type of branching in the palm genus *Hyphæne*. I could show, however, that the dichotomy of these palms, although quite distinct from any type of lateral branching existing among the Spermatophytes, is nevertheless not identical with the dichotomy in the above-named groups. The fact that axillary buds are present everywhere in these palms demonstrates the enormous distance which separates them from these groups.

Branching, however, is not only of importance in distinguishing some of the main groups of the vascular plants, but also in characterising smaller groups, especially among the Spermatophytes. It is well known that several families and genera show abnormal types of branching which can only be explained as axillary by the introduction of the notion of concrescence. The interpretation of these types of branching sometimes offers considerable difficulty; for instance, in the *Asclepiadaceæ*, where the 'extra-axillary' inflorescences usually arise between the orthostichies. In the *Solanaceæ* concrescence is also a phenomenon of general occurrence. This was overlooked by Eichler when he drew the diagrams of their flowers. In these diagrams the gynoecium is shown in an oblique position with regard to the plane of the main axis and the bract. Eichler's bract, however, is in reality a bracteole, and one of his bracteoles a leaf of the shoot which arises in the axil of the false bract and whose first internode is united with the peduncle. The true bract lies below the false bract and exactly between the latter and the second true bracteole, in such a position, therefore, that the plane of symmetry passes through its middle.

Friday, August 2.

Dr. E. P. PHILLIPS.—*A Brief Sketch of the Flora of the Environs of Pretoria.*

This deals only with the Dicotyledons which are represented by seventy-four families, just over half of the known South African families of plants. A comparison is made of the leaf, flower and fruit characters of the species with an area in the south-western region. The various growth forms in the flora are noted, and an analysis of the species, genera and families given. A short note on the affinities of the Pretoria flora concludes the paper.

Miss E. M. YOUNG.—*Physiological and Cytological Studies in the Genus *Monascus*.*

Dr. J. F. V. PHILLIPS.—*Some Important Vegetation Communities in the Central Province of Tanganyika Territory.*

The Central Province—its northern boundary lying between 4° and 5° S. lat. approx., its southern limit the Ruaha-Nzombe river (7° S. lat. approx.), bounded on the east by a line ranging between 36° 3' and 36° 5' E. long., and with its western limit varying between 33° and 34° E. long.—forms portion of the great central plateau of Eastern Central Africa. Represented are elevations from 3,000 to 6,000 feet, the bulk of the country lying between 3,500 and 4,500 feet. The country rocks are granite, gneiss and crystalline schist. Important soils are the *eluvial* red and grey sandy-loams and clays and the *alluvial* red and grey sandy-loams and clays.

The rain-bearing winds are local and variable. The mean annual precipitation, based upon all too meagre data, perhaps, has as its limits 300 and 1,000 mm. The 'short' rains fall between late October and late December with a variable dry spell in January and part of February, the heavier fall ('long' rains) being during March, April, and a portion or the whole of May.

Critical temperature data are wanting, but it seems that the mean annual air (shade) temperature as obtained in Stevenson screens ranges between 18° C. and 23° C., according to locality.

A knowledge of the nature and relations of the principal vegetation communities is indispensable to a better understanding of (a) the conservation of the soils, (b) the regulation of grazing, (c) the habitat relations, control and combat, of the tsetse-flies, *Glossina morsitans* and *G. swynnertoni*.

The aim is to record preliminary impressions of some of the more important communities and to suggest certain of their relations. More critical information is being obtained by quantitative instrumental and quadrat methods.

The communities fall readily into the following main classes :—

1. Open grass, short or long, without *incipient* or *relict* (fire) largely-deciduous, thicket elements.
2. Open grass, short or long, with *incipient* or *relict* (fire) largely-deciduous, thicket elements, scattered or in communities of variable density and extent.
3. Acacia open-woodland communities, grass-growth variable, often tall.
4. Combretum-Other spp. open-woodland communities, grass-growth variable, often tall.
5. Largely-deciduous thicket in which Commiphora spp. and other spined or rigid woody shrubs play an important part; grass-growth either absent or very sparse.
6. Deciduous thicket in which Grewia spp., Baphia, Bussea, Pseudoprosopis and trailing Combretum are the important forms; grass-growth either absent or very sparse.
7. Berlinia-Brachystegia-Other spp. woodland; grass-growth variable, depending upon soil moisture.
8. Upland Brachystegia (*microphylla*) Other spp. woodland.
9. Sub-tropical Evergreen Scrub, transitional to sub-tropical Evergreen Forest; in highlands above 5,000 feet.
10. Sub-tropical Evergreen Forest, upon moister highlands above 5,000 feet.

Within these classes the principal communities are listed and described briefly.

Dr. S. SCHONLAND.—*Some South African Plant Hybrids and the Bearing of our Knowledge of Plant Hybrids on the Theory of Evolution.*

To deal with this matter one must make it clear what one means by Hybridisation and incidentally what is meant by a species. Nobody has as yet been able to satisfactorily define what a species is. This is only to be expected, as species are only subjective conceptions and do not exist in nature. Darwin's recommendation has worked well in practice. He said: 'Systematists will have to decide whether any form is sufficiently constant and distinct from other forms to be capable of definition and, if definable, whether the differences be sufficiently important to deserve a specific name.' Many hybrids are the result of crosses between individuals of different species. These may be called *interspecific hybrids*. In view, however, of the fact stressed by Lotsy that in nature no homozygotes occur (he despairs even of ever creating one artificially), the crosses between the individuals of any heterozygous species must also be looked upon as hybrids. The writer designates these *intraspecific hybrids*. If interspecific hybrids can and often do represent or lead to

distinct forms, this may also be claimed for intraspecific hybrids which are generally included in the term 'variations.' Thus we come back to Weismann's view that Amphimixis confers an essential advantage in the modification of species.

Lotsy and Goddijn have in a recent work indicated forty-three South African plant-hybrids which are all, according to their view, interspecific. Strictly speaking they are all *assumed* hybrids, but this may pass. Forms assumed to be hybrids on fairly good grounds seem to be just as common in South Africa as in other countries. The writer is in a position to add a number to the list just referred to.

Granted that hybrids may represent or lead to well-defined new forms, the claim that hybridisation is an important factor in evolution seems to be well founded. Lotsy thinks it is the only factor, but judgment has, for the present at all events, to be held in suspense chiefly for the following reasons:—

(1) In spite of the large number of hybrids known in well-explored European countries, the species have for a long time remained unchanged. Very few new species have been discovered since intensive work has been devoted to them, and only in one case known to the writer has a hybrid origin been made likely. In South Africa we can also show that a number of species have persisted for a couple of hundred years, and in a few cases this has happened to species which hybridise freely in nature.

(2) Phytogeography and Palæontology afford numerous instances proving that species have persisted for thousands of years and even through geological ages, which one would not expect if hybridisation had the modifying influence claimed for it.

(3) Hybridisation need not necessarily be the only cause of evolution. Apogamous species vary just as much as sexually produced species. Innate causes, or causes which appear to be innate owing to our inability to analyse them, may be at play in creating new species. The known facts of bud-sports may indicate that new species may arise in the course of vegetative reproduction.

(4) In large groups of plants Orthogenesis appears to be responsible for evolution. This also seems to be the case in certain genera in the evolution of species of which the writer quotes some instances.

(5) Natural selection reigns supreme, no matter what the origin of new forms is. Co-adaptation (in Herbert Spencer's sense) cannot be expected to occur often (if at all) in interspecific hybrids, while this may happen more frequently in intraspecific hybrids. The latter seem, therefore, to have an advantage over the former in the struggle for existence.

Dr. ETHEL M. DOIDGE.—*Some Diseases of Citrus prevalent in South Africa.*

The diseases considered are those responsible for wastage in citrus fruit exported from South Africa.

The organisms responsible for the greater part of the wastage are the common moulds (*Penicillium* spp.) and *Alternaria citri*. Some account is given of recent packing experiments with fruit which had been dipped in antiseptic solutions as compared with fruit packed in specially treated wrappers. A summary is also given of work recently done in connection with *Alternaria citri*.

A brief account is given of organisms of minor or periodic occurrence in citrus fruits, and also of some blemishes which lead to breakdown of the rind and subsequent rotting by mould fungi.

Mr. J. E. VAN DER PLANK.—*A Physiological Study of Concentric Ring Blotch of Citrus.*

There is evidence to show that concentric ring blotch is probably due to physiological causes.

It is confined almost exclusively to the summer flush of growth, and only young shoots are affected. It is chiefly a disease of nursery plants and young trees, the young growth of older trees being more resistant.

It has been found that the diseased leaves and twigs are deficient in phosphorus as compared with healthy material. This is possibly partly due to a phosphorus deficiency in the soil, but is largely due to excessive growth. Several pieces of evidence indicate this.

(1) It is chiefly a disease of nursery plants, where the 'efficiency index' of growth production is greatest.

(2) It is common in nurseries where conditions are otherwise excellent for growth. It is distributed in areas with very favourable climatic conditions for the summer flush of growth. The practice of giving large quantities of growth-stimulating kraal manure to nurseries may be partly responsible, although it has been shown that green manuring is beneficial. At Buffelspoort, where the experiments were done, it was found that the young badly diseased nursery plants showed the influence of kraal manure, being much richer in such elements as potassium as compared with older trees.

The study of this disease has led to an incomplete study of the behaviour of certain storage elements during growth.

References.

Dr. E. Doidge, 'Ring Blotch.' R. A. Davis, 'Citrus Growing in South Africa,' Cape Town, 1924.

Afternoon.

Miss S. M. STENT.—*The Classification and Distribution of the more important South African Grasses.*

A revision of the genus *Digitaria* with key to the South African species and notes on their chemical composition and economic value as pasture or hay grasses. Diagnoses and illustration of undescribed species are also included.

Miss I. C. VERDOORN.—*The Botany of the Fountains Valley, Pretoria.*

This valley, which lies to the south of Pretoria and is the main entrance to the town, is the source of the Aapies River. Its geological formation is interesting, consisting as it does of the Pretoria shales and quartzite with an intrusion of dolomite in the southern portion. The natural vegetation is disturbed in parts (by man) and this short paper deals with its present aspect.

Mr. A. O. D. MOGG.—*A Preliminary Account of the Flora of Pretoria in relation to the Geology.*

Miss A. M. BOTTOMLEY.—*The Development of South African Mycology and of the Cryptogamic Herbarium at Pretoria.*

Miss L. LURIE.—*Some Fungal Wound-parasites of Trees in the Transvaal, with particular reference to the Polyporaceae.*

Prof. J. H. PRIESTLEY.—Lecture (semi-popular) on *From Lake to Veld: A Study of the Water Relations of the Higher Plant.*

Saturday, August 3.

Joint Discussion with Section C (q.v.) and D on *Gondwanaland*.

K*.—DEPARTMENT OF FORESTRY.

CAPE TOWN.

Tuesday, July 23.

Mr. C. E. LEGAT.—*The Silviculture of Exotic Conifers in South Africa.*

Prof. A. W. BORTHWICK.—*Geographical Distribution of Trees as a Guide to their Cultivation.*

Mr. G. A. ZAHN and Mr. E. J. NEETHLING.—*Notes on the Exotic Trees in the Cape Peninsula.*

Mr. G. A. ZAHN and Mr. C. H. CLAYTON.—*A Summary of the Working Plan for Tokai Plantation.*

Afternoon.

Excursion.

Wednesday, July 24.

Prof. J. H. PRIESTLEY.—*The Movement of Water and Solutes in the Tree* (Joint Meeting with Section K).

Dr. E. V. LAING.—*The Biology of the Soil and its Relation to Tree Growth.*

The knowledge already acquired regarding the micro-organisms of the forest soil indicates that the subject is of first-rate importance to the silviculturist. Just as the agriculturist has benefited from soil micro-biological research, so undoubtedly will the forester, but whereas the agriculturist is most intimately bound up with bacteriology, the forester is, as far as our present information permits of affirming, dependent more on the action of numerous fungi. The bulk of research has centred round the problem of the intimate union of fungi with tree roots, but that intimate association of bacteria and tree roots also occurs is considered possible. The union of fungi and tree roots illustrates all stages from apparently true beneficial partnership to intensively destructive parasitism. Fungi play an important part in moulding root habit or form. In view of the importance of mycorrhiza the ecology of mycorrhiza-forming fungi is of paramount value.

Afternoon.

Excursion.

Thursday, July 25.

Mr. G. A. ZAHN and Mr. E. J. NEETHLING.—*The Cluster Pine (Pinus pinaster).*

Mr. W. R. DAY.—*Environment and Disease : A Discussion on the Parasitism of Armillaria mellea, Vahl. Fr.*

The fundamental causes of disease are to be found in the inherent character of the diseased organism and the factors of environment, both physical and biological, with which it has to contend. Parasites, often regarded as the chief cause of disease, are only one factor in this complex of forces bringing about a diseased state, and frequently by no means the most important. When a disease is investigated it is necessary, therefore, to ask what is really its primary cause, and what are the factors which make it possible for this to act. Only when this is understood is it possible truly to appreciate the importance of other factors acting secondarily. If the root-rot of trees associated with attack by *A. mellea* is examined, what is the rôle of this fungus seen to be? The evidence brought forward here all goes to show that it is always a secondary cause of disease infecting and killing trees that have already become debilitated owing to other causes. These are sometimes fairly obvious, such as severe drought, or defoliation by insect larvæ; but in many instances the primary cause of disease is more obscure, and the fungus itself may appear to be the initial cause of disease. However, in no instance where the matter has been investigated has this been found to be true, and the manner in which the susceptibility to infection and to death after infection varies goes to confirm the secondary rôle of the fungus as a cause of disease. With *A. mellea*, therefore, as with many other parasites, and especially those affecting forest trees, efficient control depends on a proper understanding of the environment in which the trees grow, and of the conditions necessary for healthy tree growth.

Mr. T. A. McELHANNEY and Mr. R. D. CRAIG.—*The Canadian Forest Industries.*

1. *Historic Place of the Forest in National Life.*

Since the earliest days of the French régime the products of the forest have furnished a natural and abundant source of industrial prosperity in Canada. Oldest of all is the fur trade, which continues to yield pelts to the value of nearly \$20,000,000 a year.

The square timber export trade flourished during the first three quarters of the nineteenth century, and was followed by the sawn lumber industry that reached its crest in 1911, since which time the growth of the present enormous pulp and paper industry has been the outstanding feature.

2. *Relative Economic Importance of Forests among Natural Resources.*

In value of production the forest industries rank second only to agriculture, have nearly twice the value of the mines, and almost ten times the value of the fisheries. The total forest resources hold a key position in respect to the national trade balance. In 1927 the value of the forest products exported was \$280,000,000 with imports of only \$36,000,000, leaving a favourable trade balance of \$244,000,000. This figure considerably exceeds the total favourable national trade balance for that year, which was approximately \$221,000,000.

3. *Extent and Nature of Forest Resources.*

Canada's forest industries have grown up as a result of an abundance of accessible timber. There is in Canada about 1,150,000 square miles of land better suited to producing wood crops than food crops. Of this area some 310,000 square miles now carries accessible timber of merchantable size, while on 555,000 square miles there are young growing stands within reach of existing transportation facilities. The remaining 285,000 square miles is at present commercially inaccessible. Though the original forest wealth of the country has been depleted by fire and exploitation, there is estimated to be approximately 225,000 million cubic feet of timber of merchantable size, 80 per cent. of which is of softwood or coniferous species. The softwoods, such as pine, spruce and fir, extend from the Atlantic to the Pacific, but the best hardwoods, such as birch, maple, oak, &c., are found in southern Ontario, Quebec and the Maritime Provinces. In the eastern provinces white pine is perhaps the most valuable softwood, while in British Columbia Douglas fir, red cedar, hemlock and Sitka spruce are the principal woods. Various species of spruce and fir extend across the continent and, though used extensively for lumber, are the most important pulpwood species.

4. *Current Forest Depletion and Relative Accretion.*

There are to-day in Canada close to 7,000 industrial plants wherein wood or paper is the primary basic material used. To supply this domestic market, together with the heavy export demand, about 1,200,000 acres are cut over annually with a total yield now approaching three billion cubic feet, and as yet there is little information regarding the natural increment which is accruing in the forests, but a national inventory of the forest resources is being organised which, it is hoped, will reveal the relation between increment and depletion as well as the extent of the resources.

5. *Forest Products Utilisation in Canada.*

The manufacturing industries dependent on the forests fall into two main groups, the lumber industry, which includes the manufacture of sawn lumber, lath and shingles, and the pulp and paper industry. As measured by the net value of products and wages and salaries distributed, the pulp and paper industry is the most important manufacturing industry in Canada, and the lumber industry ranks second. In addition to these industries the production of poles, piling, fuelwood, mine timber, fencing material and pulpwood and logs for export is an important factor in forest production. The further manufacture of lumber in planing mills, sash and door factories, furniture, cooperage, box and implement manufacturing plants; practically

doubles the industrial value of the lumber, and the plants manufacturing paper bags, boxes, roofing paper, &c., materially enhance the sale value of the pulp and paper they use.

The total sale value of the products of the forest is approximately \$530,000,000 annually. Of this the pulp and paper industry furnishes \$219,000,000, the lumber industry \$111,000,000, unmanufactured woods products \$80,000,000, and the finished wood products \$120,000,000.

While Canada is a very large exporter of forest products, she is not entirely self-supporting in this respect. In 1926 the imports of forest products were valued at about \$36,000,000. This is largely accounted for by the importation of expensive hardwoods such as oak, walnut, mahogany, gumwood and some of the rarer woods used particularly in the furniture industry.

The lumber industry, which for many years was centred in eastern Canada, has gradually shifted to British Columbia, until now Douglas fir occupies first place in Canada in the amount of material sawn. Douglas fir also figures very prominently in the export trade of Canada on account of its pre-eminent position as a structural and general utility timber.

The Federal Government of Canada, by the establishment of forest products research laboratories, has been active in stimulating a more intensive and economical use of wood. Beginning with one organisation in 1913, the work of these laboratories has rapidly expanded until there are now three such institutions in the Dominion Forest Service actively engaged in research in wood utilisation. The main laboratories are located in Ottawa, with a branch laboratory in Vancouver, which concentrates on the problems relating to British Columbia timbers, and a pulp and paper laboratory located in Montreal, maintained in co-operation with the Pulp and Paper Association of Canada. This is probably the most completely equipped pulp and paper laboratory in existence.

Afternoon.

Start of tour to forests at George and Knysna.

JOHANNESBURG.

Wednesday, July 31.

Dr. I. J. CRAIB.—*Moisture versus Light as the Limiting Factor in Forest Development.*

Mr. J. J. KOTZE and Mr. C. S. HUBBARD.—*The Growth of Eucalypts in the Sub-tropical Plantations of the Transvaal and Zululand.*

Mr. A. J. O'CONNOR and Dr. I. J. CRAIB.—*Silvicultural Investigations into Wattle Cultivation.*

Afternoon.

Excursion.

Thursday, August 1.

Mr. H. A. READ.—*Mining Timber in the Witwatersrand.*

Mr. M. N. SCOTT.—*Notes on Exotic Coniferous Timbers grown in South Africa.*

Afternoon.

Excursion.

Friday, August 2.

Mr. E. F. ENGLISH.—*Laboratory Studies in Pulping some South African Woods.*

Mr. N. B. ECKBO.—*Moisture Content of Wood.*

Mr. G. A. WILMOT.—*Timbers suitable for Match-making.*

Dr. J. BURTT DAVY.—*The Distribution of the Forest Flora of Nyasaland.*

Nyasaland occupies a somewhat narrow 'rift' valley running (roughly) north and south, and is isolated from the adjacent territories of Northern Rhodesia on the west and Mozambique on the east by fairly high ranges of mountains. This isolation is reflected to some extent in the local forest flora. Numerous endemic species, and local varieties or forms of more widespread genera and species, are met with, e.g. *Podocarpus milanjanus*, *Widdringtonia whytei*, *Monodora stenopetala*, *Uvaria nyassensis*, and local 'varieties' of *Sterculia triphaca* and *Maerua angolensis*. There is, of course, a large admixture of the usual pan-tropical African species, such as *Adansonia digitata*, *Pterocarpus angolensis*, *Capparis tomentosa* and *Securidaca longipedunculata*.

But the striking feature of the flora is the large number of species which show a definite north and south distribution. Of these, numerous species range north to Kenya and Abyssinia, and many find their southern limit of distribution in Nyasaland (e.g. *Millettia usaramensis*). But a number of them extend south through the Chimanimani Mountains of Southern Rhodesia, to the Houtboschberg range of the North-eastern Transvaal, and a few, such as *Apodytes dimidiata*, have found their way along the Drakensberg and the mountain ranges of the Eastern Cape, westward to Knysna and down to sea-level.

The southern distribution of these Nyasaland temperate montane species is of particular interest, as it raises the question, How did they cross the Zambesi basin? This low-lying belt of hot, tropical forest forms a barrier just as the larger basin of the Congo forms a vegetation barrier. The question suggests the possibility of the species distribution having taken place before the geological formation of the Zambesi basin.

The occurrence of certain Eastern Cape and Knysna species on the Nyasaland mountains suggests, also, that other trees indigenous to those areas, or successfully cultivated there, could also be grown in parts of Nyasaland.

Mr. PAUL TOPHAM.—*The Influence of Man on Forest Environment in Northern Nyasaland.*

SECTION L.—EDUCATIONAL SCIENCE.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 430.)

CAPE TOWN.

Tuesday, July 23.

GENERAL EDUCATIONAL PROBLEMS IN SOUTH AFRICA :—

(a) Dr. E. G. MALHERBE.—*Education and the Poor White.*

(b) Dr. W. J. VILJOEN.—*The Small Rural School.*

The problem of the rural school is more acute in young countries than in older and more settled countries; but even in the latter it is not absent. The average rural school is both more costly and less efficient than the average town school.

Efforts must be made to lessen the disparity in educational opportunity between the town child and the country child. The best solution is to centralise rural school facilities. Ideally, a rural school should serve a circular area of six miles' radius—or even a larger area, if motor transport is available.

In spite of efforts to centralise, however, it will be a long time before the single-teacher school is entirely eliminated. In schools of this type the classes should be grouped and the curriculum reduced to essentials. A modified form of the 'Dalton Plan' will probably prove to be the best solution.

The small rural school should be related as closely as possible to its environment. Topics of rural point and reference should figure largely in the course, and nature-study and school gardening should be introduced as the qualifications and aptitudes of the teachers and the conditions of the locality permit. The 'project plan' can be effectively employed in small rural schools. 'Club work,' on the American lines, is also very valuable.

(c) Dr. C. G. CILLIE.—*Historical Survey of Bilingualism in the South with its Educational Implications.*

When the English finally decided to retain the Cape, in the second decade of the nineteenth century, they changed their policy and attitude towards the Dutch population. Although there is nowhere a definite pronouncement on the matter, there is sufficient evidence to show that the intention was to Anglicise the Dutch inhabitants. For this purpose Scottish Presbyterian Ministers were invited from Scotland to fill the vacancies in the Dutch Reformed Church. Although these men had to spend some time in Holland before coming here in order to learn Dutch, their manses or parsonages became centres for the spread of English ideas, English civilisation and the English language. And after Lord Charles Somerset had announced in 1822 that from a certain date English would be the only official language in the country, he imported a number of teachers from Britain who were stationed at certain well-selected rural centres in the so-called English schools. These teachers were under instructions to teach the young Dutch mind in English and the language of intercourse between master and pupil was to be English exclusively. These were free schools.

With few exceptions these schools were failures, and the system and the policy were changed in 1840. Some of the schools where the instruction was given in English were maintained under the name of 'Established' schools, but alongside there were started schools that received grants-in-aid from the Government under certain conditions, one of which was that English was to be one of the subjects of instruction. The medium was left to the choice of the parents of the pupils. In spite of this freedom of choice English remained the sole medium of instruction throughout, because the inspection and the examinations were conducted exclusively in English, and gradually everybody had come to consider education, or at least schooling, as synonymous with learning to speak and to write English. Even their mother-tongue was taught to Dutch-speaking children through English. It was a rare privilege, and certainly a great experience, to learn one's mother-tongue through a foreign language—a privilege and experience enjoyed, as far as one knows, only by young Dutch-speaking South Africans.

Political events such as the first War of Independence in 1880, the Jameson Raid and the war of 1899–1902, made Dutch-speaking South Africans realise that they were a distinct nationality. There was a different attitude on their part towards the English and the English language. Their leaders, some of whom were young men who had studied at foreign universities, were intensely national, and concentrated their energies on the rights of the Dutch language in the Civil Service and in education. The Milner régime in the Transvaal and Orange Free State after the war, which had practically banished the mother-tongue of the Boer people from the schools, roused the Dutch in the Cape Colony. The result of this activity and agitation was the insertion in the Act of Union in 1909–10 of clause 137, by which English and Dutch received equal rights as official languages. Soon after Union the various provinces passed legislation which made instruction through the mother-tongue compulsory up to the standard of compulsory school attendance. On paper at least we may say that every child in a Government school in South Africa is receiving instruction through its mother-tongue up to the stage which we call standard six, i.e. throughout the primary school, and practically every child learns both English and Dutch in those schools. We are, therefore, trying to be not merely a bilingual country but a bilingual nation.

The question naturally arises how this ideal can best be realised. Commercially and culturally English and Afrikaans are not on a footing of equality, and consequently the Dutch have all along the line been far more eager to learn the English language than the English to learn Afrikaans. And very many leaders of educational thought in our country have been and still are of opinion that the best and quickest way to teach the second language to Afrikaans-speaking children is to make them study all their school subjects in English. But, curiously enough, this theory was not advanced in the case of English-speaking children who had to master Afrikaans. Except in the Argentine Republic, where teachers who are preparing to teach foreign languages get their instruction in the training colleges through these foreign languages, one knows of no country where *e.g.* history is taught in a foreign language in order to teach them that language.

On educational grounds there can be no argument advanced against mother-tongue medium either in a bilingual country or in any other country. But there may be objections on other grounds. There may be a dearth of suitable teachers who know the vernacular of the children to be taught as we have it, *e.g.* in India and among the native races in Africa. There may be no text-books in the language, or the language may not be sufficiently developed to teach through it. Or the ruling nation may be afraid lest the allowing of two or more language groups might land them in all manner of political difficulties. The American policy of Americanisation is a good example of this. Rhodesia furnishes another example. This experiment was tried on a large scale in Poland in the nineteenth century, and is being tried now in the Tyrol.

Discussion : Prof. F. CLARKE.

Wednesday, July 24.

Joint Meeting (Sections J, L) on *Psychological Tests in relation to Education and Vocational Guidance*. (See p. 378.)

Thursday, July 25.

Presidential Address by Dr. C. W. KIMMINS on *Modern Movements in Education*. (See p. 217.)

EXAMINATIONS AND THE SECONDARY SCHOOLS :

(a) Mr. J. L. HOLLAND.—*Examinations leading to the Secondary School*.

I propose to discuss the group of examinations which have been established by the Local Education Authorities in England and Wales for the purpose of regulating the free admission of ex-elementary school pupils to the public secondary schools : they are not the only examinations, but they are the most important. The local education authorities concerned are the Councils of the Counties and County Boroughs, appointed to this service by the Education Act, 1902. That Act created a partnership between them and the State, under which the Authorities provide the service and the Board of Education decide whether the provision is adequate, the cost being divided between the two.

It was the first appearance on the Statute Book of the conception of local responsibility for secondary education. Elementary education, on the other hand, had been on this basis since Forster's Act of 1870 : for thirty years it had been organised and developed by a Government Department and local School Boards, neither of which had any concern with secondary education. In consequence, our elementary and secondary schools are not yet related one to the other in a national system of education. Since 1902 great progress has been made with the development of secondary education and the co-ordination of the two types of schools. At the present time nearly 40,000 children are selected each year from the elementary schools for free secondary education, that is, about one in every nine elementary school children of the appropriate age. With this selection we are now concerned.

Examinations are imperfect instruments, but it is submitted in the light of past history and in view of the numbers involved, that an examination to which all the elementary school children of the area have access is the only practicable means of making a reasonably just selection and one which public opinion will consider fair.

A typical Area examination is described and certain debatable questions posed for discussion.

Should the examination be compulsory or voluntary? The present practice embraces both, with a tendency toward compulsion.

What is the appropriate age? Eleven plus is now very generally chosen.

What should the subjects of the examination be? Usually they are English (including essay writing and a dictation test) and arithmetic (including a speed test). The assessment of essays presents special difficulties.

To what extent should the teachers co-operate? Practice varies. Examination is itself an art calling for skill of a kind which is not necessarily developed in the classroom.

In what way can account be taken of the previous work of the candidates? A plea is here made for a school record.

Should the candidates be examined orally or only in writing? Oral tests, as at present conducted, present many difficulties.

The use of Intelligence Tests.

Area examinations are not yet universal, but they are likely to multiply during the next few years. The age of eleven plus will soon be the critical age in the child's school career. Local authorities, guided by the Hadow Report, are re-organising their elementary schools into junior and senior schools, the dividing line being drawn at that age. When this is finished there will be a triple selection to make, namely, for the secondary school, the selective central school (which used to be known as the higher elementary school) and for the senior school. Children whose parents can afford to pay fees will also have to prove their fitness to profit by secondary instruction. It is safe to predict that the Area examination will be used to decide all these issues. Our educational history, both elementary and secondary, is full of warnings of the mischief done by ill-conceived examinations. Administrators, teachers and examiners, must, therefore, keep these new examinations under perpetual review; they must not be allowed to become stereotyped and conventional.

(b) MR. E. R. THOMAS.—*Examinations in, and at the end of, the Secondary School Course.*

External examinations useful and necessary, but much in need of reform as to :—

- (a) their conduct,
- (b) the appreciation of the value of the results.

Suggestions for improvement :—

- (a) (i) Increased co-operation of teachers—an instance quoted in detail.
- (ii) Closer contact between examiner and pupil—an example given.
- (b) (i) Results must not be used for invidious comparisons between schools.
- (ii) Examinations provide indirect measurements of results, and are indifferently conscious of the process by which those results have been obtained.

(c) DR. J. F. BURGER.—*Examinations in the Secondary Schools, with special reference to South Africa.*

1. Clarity as to the aims of the secondary school necessary before the examinations can be discussed.

2. In South Africa the aim of our whole system of education was (until quite recently) to train an intellectual élite—which meant 'those possessing knowledge,' and not necessarily 'those able to make use of it.'

3. Our system was thus a long educational ladder with the 'infant' classes at the bottom and the matriculation examination at the top. This examination was the goal of all educational effort in our schools.

4. Realisation of the enormous intellectual waste and the evil effects of such a system has led to reforms in recent years. These reforms, however, are far from complete, and a total reorganisation of our secondary education is imperative, with a corresponding reorganisation of our examination system.

5. This reorganisation must rest on an insight into the demands of modern South

African society and a knowledge of the child's mental development—it must be made from a sociological as well as a psychological point of view.

6. The sociological consideration demands that the pupil should follow the bent of his talents, should be fitted for the work in society which he can best do, *i.e.* for a suitable profession.

7. The psychological consideration demands that the school education should adapt itself to the different stages of mental growth of the pupil and should continue till well after the commencement of adolescence.

8. Hence we get :—(a) education up to the beginning of puberty : the primary school ; (b) from early puberty to about the 17th year : the secondary school—from which it follows that we should have secondary education for all.

9. The core of secondary education must be the main interest of pupil, *i.e.* his future profession.

10. Therefore, different types of secondary schools to prepare for different types of professions. Here the first examinations come in : test of the pupil's talent or special ability. It is here where the psychologists can render a great service to education, *viz.* by devising tests to show the aptitude of the different pupils for suitable professions. At Stellenbosch University much useful work in this direction has already been done. With the aid of such tests, combined with the opinion of the parents and the primary teachers, it should be possible to avoid the many mistakes of 'misfits' and to put every child on the road towards his life's work.

11. The secondary school will have to cater for pupils entering or preparing for all sorts of professions which may be divided into three great classes :

(a) Those demanding a high standard of theoretical knowledge and mental power (*e.g.* the 'learned' professions : law, medicine, theology, scientific research, &c.). This class of profession cannot be entered by the pupil at the age of 13 or 14, but requires a long and thorough theoretical preparation and clearly points the way to the University. In this case the secondary school course would have to be a preparation for the University, and the final school examination will be the entrance examination of the University. This examination will have to test : (i) the knowledge and intelligence of the pupil : (ii) his capacity for scientific research ; (iii) his health ; (iv) his character. The opinion of doctor and teacher (and other educators) will suffice for Nos. (iii) and (iv), while a combination of the usual matriculation examination and the mental (or intelligence) test will give fairly trustworthy results for No. (i). For No. (ii) the pupil should be given a task entailing research work with sufficient time to do it in, or be allowed to present work of such a nature done during the last year of his school course.

(b) Professions requiring a great deal of theoretical knowledge as well as practical skill (*e.g.* commerce, banking, accountancy, clerical, technical, &c.). Here practical and theoretical work should go hand in hand, and the final examination should consist of a practical as well as a theoretical part. Successful pupils should then be considered as fully qualified for their profession.

(c) Those which are eminently practical, which require no great preparation beyond a certain period of apprenticeship, and which pupils of 13 or 14 can enter at once either as apprentices or as qualified workers. The type of secondary school to meet the needs of such pupils will be very much like our present continuation schools, and will have to accommodate the bulk of our youth. The profession must be the core round which the school education will have to group itself. From the profession the school teaching must start to broaden the interests of the pupil, to show him his relation to society, his value to the community, and his responsibilities as a member of that community. Aim of this type of secondary school should be to make of the worker an intelligent citizen, an educated man with broad interests, a liberally educated human being.

No final examination should be held here—a certificate from the principal that the approved course had been absolved and a testimonial as to conduct should be sufficient. The only examiner for this type of pupil and this kind of secondary school is life itself.

Followed by Discussion—Mr. GRANT, Miss E. R. CONWAY.

Sir RICHARD GREGORY.—*Report on Science and the School Certificate Examination.*

Friday, July 26.

THE TEACHING OF SCIENCE IN SCHOOLS :

(a) Prof. H. B. FANTHAM.—*The Teaching of Biology.*

The teaching of biology in schools is considered more especially from the South African standpoint, but the general principles apply to any country. At last it is becoming recognised that a knowledge of biology is a necessary part of a liberal education. Also, the present need of trained biologists in the Empire indicates the economic importance of the subject.

In the Cape Province biology is taught in secondary schools to both sexes. In the Transvaal high schools, generally, botany is taught to girls and chemistry and physics to boys. As a result of much propaganda, about two years ago the Transvaal Education Department appointed a committee of head masters, inspectors, science teachers and University professors to consider the teaching of science in high schools. After much discussion, a syllabus of general science was proposed, in which both physical and biological sciences, with physiography as a centre, were grouped and correlated. At first, a five years' course of general science was considered, special attention being devoted to the first three years' work, at the end of which period about 85 per cent. of the pupils leave school, having reached Form III. (or Standard VIII.) and being about 16 years of age. Ultimately a three years' course of correlated general science was recommended for high schools, with a divergence into the study of either biological or physical sciences during the fourth and fifth years. Care was taken to avoid too early specialisation. This scheme is to be introduced into Transvaal high schools in 1930, and will form a subject for the school leaving certificate. Nature study is taught in the primary schools, but at present it has hardly realised expectations, though it should form a foundation for biological work in high schools.

The usual objections of expense, lack of suitably trained teachers and 'unpleasantness' of the subject have had to be faced and some still have to be overcome, especially the lack of teachers. The Universities might be asked to offer special courses, particularly in animal biology, for teachers.

The study of both animal and plant biology is included in the three years' course. It is recognised that the syllabus submitted is a wide one. All the subjects should be attempted, but scope is allowed for individual interpretation and for variation in the local environment. Uniformity of detail in such a syllabus is undesirable and impracticable in South Africa. Ecological, physiological and economic factors must be considered, and form and function not dissociated. Insistence is laid on the acquisition of first-hand knowledge, on accurate deductions therefrom and on the study of biology as a training for membership of a civilised community.

The different topics of each year's syllabus should be taught at the appropriate season of the year. In South Africa biological work will be done more especially in the spring and autumn when fresh material can be obtained, most of the summer being long vacation. Pupils must be encouraged to collect, handle and examine living specimens of the animals and plants they study, as well as to make contributions to the school garden, vivarium, aquarium and school museum. The nature calendar kept by each scholar should be so compiled that it becomes a good ecological record of the neighbourhood. Experimental work in biology must be undertaken by the pupils. Dissection should be done by them individually in their last year. Correlation and application of processes observed in plants and animals with what occurs in man are necessary, forming a practical introduction to hygiene and further indicating the close association of biology with human life. Ideas of sex and of evolution are gradually developed as natural occurrences. Attention must be given to animal and plant excitants of disease (e.g. of malaria, redwater, bilharziasis, fungoid diseases); such are of interest and practical importance and always appeal to young people who are intensely utilitarian.

Biological studies serve to introduce pupils, in the later years of their course, to the work of great investigators such as Darwin and Pasteur, by reference to carefully selected parts of their works. The literary and cultural aspects of natural science are thus inculcated.

The syllabuses for high schools in the Transvaal in general science (three years' course), and those in biological sciences (two years' course) are presented for discussion.

(b) DR. LILIAN J. CLARKE.—*The Teaching of Botany in Laboratories and School Gardens.*

It is now generally agreed that the study of living things should form part of the education of every child.

The problem is how best can biology be taught so, that in addition to developing interest in living things, there may be real training in scientific method.

At the James Allen's Girls' School, Dulwich, plants are studied as living things by means of the pupils' own observations and experiments in laboratory and garden.

Work in the Laboratory. Lantern Slides.

No textbooks are used up to the Matriculation stage, no set lessons or dictated notes are given. A well-lighted laboratory, in which pupils have adequate space and opportunity for individual work, has been of great help in enabling them to learn by means of the experiments they make. It is useful to have benches below the windows fitted with sinks, and with water and gas laid on.

If possible there should be a dark room.

Many experiments can be made by every member of a class, such as those showing the influence of gravity and light on the direction of growth of roots and stems, the presence of pores in leaves, the conditions necessary for germination, the processes of photosynthesis, respiration and transpiration.

An interesting piece of work is finding out which elements are necessary to the life of a plant. At Dulwich girls have grown the same perennials for many years in food solution, and have succeeded in growing fifteen generations of plants that have never been in the soil.

If each girl makes her own experiments, or two girls working together, and records are kept every year, reference can be made to numbers of experiments, and not only to one or two, when framing a general proposition. In biology generalisation should not be made on insufficient data any more than in any other science. Also there should be careful examination of the conditions of the experiment, and control experiments should be made.

At the James Allen's Girls' School there are records of hundreds of experiments on different plants showing the work of a green leaf in photosynthesis, of more than two thousand two hundred experiments showing the function of pollen.

Botany Gardens as Outdoor Laboratories. Lantern Slides.

The Botany gardens at Dulwich have been most valuable in affording opportunities for studying the living plant by means of experiments. They have been of great value also on account of the interest they have aroused in plant and animal life, and from an æsthetic point of view. They have always been in charge of the girls themselves; the work is voluntary and is not done in the school teaching hours.

Last year nearly 300 girls had Botany gardens. The gardens have been made and developed in response to the need of the Botany teaching.

They now consist of:—a lane, an oakwood, two ponds, freshwater marshes, a heath, peat bogs, Natural Order plots, several salt marshes, a pebble beach, a sand dune, a miniature cornfield, and plots for pollination experiments.

Many things are learnt incidentally, such as the magnitude of vegetative reproduction in some plants in sand dune, pond and wood (one sand sedge plant was put in the sand dune; in less than eight years more than seventy-two thousand plants had been removed, and yet numbers remained in the dune).

Great facilities are afforded for experiments on climbing plants, experiments on various soils, photosynthesis experiments, pollination experiments, experiments on the effect of variation of light intensity on the ground vegetation of the wood, some Mendelian experiments, and many other experiments.

Study of Animals. Lantern Slides.

In several classes the study of animal life is an important part of the work in addition to the study of plant life. The ponds, the lane, the marshes, the wood and other parts of the Botany gardens supply a wealth of material.

Botany gardens are invaluable when living things are studied, whether more stress is laid on plant life, or more on animal life.

Followed by Discussion : Prof. L. T. HOGBEN, Dr. S. H. SKAIFE, Prof. D'ARCY THOMPSON.

Sir JOHN RUSSELL, F.R.S.—*Report on Training for Overseas Life.*

Discussion : Sir ROBERT FALCONER, Sir ROBERT GREIG.

Dr. C. W. KIMMINS.—*Report on Formal Training.*

JOHANNESBURG.

Wednesday, July 31.

EDUCATION AND THE NATIVE RACES.

(a) Dr. E. H. BROOKES.—*Native Education in relation to National Policy.*

1. The special aspect of the subject considered in this paper is the influence of considerations of national policy upon native education. The main thesis of the paper is that most of the differentiation between Native and European education in South Africa arises from political and economic, not from pedagogical, causes.

2. One illustration of this thesis is the need for constant pleading, both in South Africa and in the Southern States of the U.S.A., that education should be given to the black man at all. Opposition to such education is rarely, if ever, based on genuine doubts as to the black man's improvability.

3. Similarly, the system whereby the majority of Native schools are controlled by missionary bodies and not directly by the State is to be explained not so much by appreciation of the missionaries or of religious education as by the State's attitude, which is one of toleration of Native education rather than active support of it.

4 and 5. Like causes explain the reluctance to make Native education either compulsory or free.

6. The question of linguistic medium is more complex, but even that turns much more on considerations of national policy than on pure pedagogical arguments. Most segregationists favour the use of the vernacular as medium, whilst those who advocate 'equal rights for all civilised men' tend to favour English. Somewhat surprisingly, most Native leaders favour English as medium, also on political grounds, as they now view all discrimination with not unmerited suspicion. English is gaining ground over the vernacular tongues and has snatched from Afrikaans—owing to the late arrival of the latter in the field of Native education—a golden chance of becoming the cultural medium of five million people. The more Natives control their own education, the more English will prevail.

7. The spirit and general aims of Native education cannot be different from the spirit and general aims of education throughout the world. Any difference could only be justified on the ground that Native and European psychology differed radically. This view we cannot accept, if only from a careful study of the similarity between the phenomena of conversion and the religious life among the two groups.

8. Detailed differences of syllabus must arise in existing circumstances, but many such differences have been occasioned solely by considerations of national policy, and not by pedagogical reasons at all.

9. It must be repeated that there is no special or separate philosophy of African education.

10. This statement must be applied *inter alia* to the South African Native College at Fort Hare, which is rapidly evolving into a University for all non-Europeans in South Africa. With a study of the immense possibilities of this Institution the paper closes.

Discussion : Prof. R. F. A. HOERNLÉ, Mr. D. D. T. JABAVU.

(b) Dr. C. T. LORAM.—*A National System of Native Education.*

1. The white man's attitude towards Native education in so far as he has expressed it has varied at different times. Originally education was the handmaid of religious propaganda; then, as the white man wanted semi-skilled labour, the emphasis was laid

on industrial and agricultural education. Nowadays, with increasing demand for segregation and at the same time, illogically enough, for black unskilled labour, and the colour bar in industry, Native education must aim at (i) vernacular instruction ; (ii) agricultural activities ; (iii) elementary standards. As far as the Native has been able to express his aim it has been towards a literary education closely resembling that given to Europeans.

2. History of Native education shows these influences very clearly. Landmarks : (i) the early mission schools in some cases with European and Native children on the same school bench ; (ii) the separate department of Native education in Natal as distinct from the joint department in the Cape ; (iii) the slow development of Native education in Transvaal and Orange Free State ; (iv) the publication of Loram's ' Education of South African Native ' and the emphasis on adjustment ; (v) the Cape Native Education Commission of 1918 and appointment of a Chief Inspector of Native Education ; (vi) the policy of imposing upon separate Native taxation the financial responsibility for Native education and the increasing influence of the Native Affairs Commission and Department.

3. There is need to-day for reorganisation. Present system defective inasmuch as (i) there is dual control between Union Government as the body providing the funds and directing the policy, and the Provincial administrations who administer the systems ; (ii) there is to-day school provision for only 25 per cent. of the Native children of school age ; (iii) there is lack of co-operation between the Native schools and the bodies responsible for Native administration and development ; (iv) the whole progress of South Africa is impeded by the low productivity achievement of the Native people.

4. Administrative reforms needed are (i) the transfer of Native education to the Union Government and the creation under the Native Affairs Department of a sub-department of Native Education working in close co-operation with the (to be created) departments of Native Health and Native Agriculture ; (ii) the division of the country into five administrative units each in charge of a Chief Inspector of Native Education, viz. the Xosa-speaking group (*i.e.* S.E. Cape and Transkeian Territories), the Zulu-speaking group (*i.e.* Natal and Zululand), the Sechuanan-speaking group (*i.e.* British Bechuanaland and the Western Transvaal), the Sesuto-speaking (Orange Free State and Eastern Transvaal), Johannesburg and Reef groups (to be administered from the head office in Pretoria). The inspection and supervision of schools to be carried out by inspectors and Native supervisors (one inspector and three supervisors to take charge of 200 schools).

5. Financial reforms needed (i) the whole of the Native Direct Tax of approximately £1,250,000 to be made available for Native education, using that term to cover agricultural, industrial, health training as well as ordinary school work ; (ii) provision to be made whereby local communities desirous of higher and better education may tax themselves therefor ; (iii) Missions while allowed and encouraged to conduct schools to be relieved of all financial responsibility for Native education ; (iv) all officials and teachers to be placed on approved salary scales to be paid by Government with pension rights on a contributory basis.

6. *Organisation* : (i) steady replacement of mission schools by Government schools, on committees of which missions are represented ; (ii) vigorous development of principle of local responsibility through school committees ; (iii) consistent policy of school consolidation to prevent overlapping ; (iv) employment of Natives wherever possible ; (v) rapid extension of smaller ' bush,' ' rural,' or tribal schools ; (vi) use of schools as community centres for all types of Native development ; (vii) extensive use of home demonstrators working with schools as centres.

7. *Curriculum* : (i) Reform of curricula in light of Native changing needs ; (ii) the essentials of Native education, moral training, health, the use of the environment, including the three R's, agriculture and industry, development of home life, recreation ; (iii) uniform system of school and teachers' examinations.

Discussion : Mr. RHEINALLT JONES.

(c) Mr. P. A. W. COOKE.—*Tribal Education.*

This paper is based chiefly on observations made by the writer himself during a year of field work amongst the Bomvana of the Transkei. This work was undertaken in 1927 with a grant made by the Department of Social Anthropology, University of

Cape Town. The Bomvana are a people still in a very backward condition, and the difficult nature of their country has resulted in the persistence of tribal custom in a more or less pure form up to the present time.

PART I.

Tribal Education as a System.

(a) To understand an educational system the entire social system to which it is directed must be brought into focus. The social organisation of the Bomvana will be described briefly so as to indicate the manner of life and the type of individual which the system of education is designed to produce.

(b) Bomvana ideals of life. How a man grows in the sight of his fellows, aims and morality.

(c) The organon of tribal education is not knowledge as we understand the term. It is chiefly ritualistic. A brief analysis of typical rites of passage, dances, &c., to demonstrate this point.

(d) Initiation of boys and girls as educative processes. The case of tribes who have abandoned these rites.

(e) Specific education, *i.e.* of witch doctors, chiefs, lightning doctors, iron doctors, &c. The parallel between the social position and the education of the specialists. The specialist is always the ordinary man plus some extra power, and his education is thus the ordinary course plus a specific training.

(f) Economic training. The dichotomy of sex. Men's work, women's work. Who teaches these arts?

(g) The agents of tribal education. The family is the true social unit and accordingly it is the agent which undertakes the economic, sib, religious and tribal or 'civic' education.

PART II.

Tribal Education as a Basis for Future Work.

Reconstruction or education for the adaptation of the tribal native to suit or conform to European Civilisation must be viewed chiefly from the viewpoint of satisfying needs which the Native feels himself. By satisfying these 'needs' further advance can be assured. Such headings as the following will be briefly considered together with the basis, which the system of tribal education already provides in each case:—Economic, informational or functional needs (*e.g.* reading and writing), philosophical and religious, recreational, &c.

Discussion : Mrs. R. E. A. HOERNLÉ.

(d) Mr. D. D. T. JABAVU.—*The Professional Education of South African Natives.*

The education of the aboriginal people of South Africa in the professions began with the two professions of Teaching and the Ministry as a result of the advent of European missionaries. About eighty years ago a number of secondary schools were founded under missionary auspices to train Native Africans to go out among their folk as teachers and preachers. The level at first reached was quite modest, being the equivalent of two or three years' tuition after the sixth standard; but it has steadily risen until we have now got about a dozen aboriginal men and women whose attainments will compare favourably with those of the best in the Western countries, namely, the qualifications of a British graduate possessing a post-graduate education diploma. One of these has been appointed an examiner in the B.A. degree for the University of South Africa.

In the case of the Ministry several Natives have secured the Doctorate of Divinity at the University of Rome, whither they were sent by the Roman Catholic Church. Those who are trained locally by the various religious denominations usually undertake theological training after obtaining the equivalent of a Junior School Leaving certificate, and in this training they spend from four to seven years, and we have one who took a course equal to a degree before going into training.

In Medicine the requirements of the medical associations in both Great Britain and South Africa have limited the number of black practitioners down to the very few who can financially manage to proceed overseas and take the course there. Notwithstanding this handicap, we have seven Native doctors possessing qualifications

from either Edinburgh, Glasgow or Birmingham, with additional credentials, in the case of five of them, from Dublin, Budapest, Toronto and Meharry medical colleges.

In Law the number of fully qualified men is also seven. Four of these went through Lincoln's Inn and the Inner Temple (London) as barristers; one served his articles in London as a solicitor, and two have qualified as attorneys within South Africa after serving articles with local European attorneys.

The following questions naturally arise in connection with the professional education of the Bantu: Is there a need for such men? Do the Bantu races possess the capacity to reach the exacting standard demanded by these professions? What are the opportunities available for such an education and for the practice thereof?

In answer, we may state that:—

(1) The country is in sore need of such men because the Native people can best be served by their own sons and daughters, all other things being equal.

(2) The actual success achieved during the last decade has gone to prove beyond all shadow of a doubt that, given a favourable chance, the Bantu, notwithstanding their brief tradition in civilisation and their present lack of a cultured social background, have an inherent intellectual ability that enables them to reach a stage of equality when pitted against the brains of those races that lead in modern civilisation. In recent public examinations they have achieved first grades at the Junior certificate, at the Matriculation and in the Majors of the B.A. degree, as well as record passes in medicine.

(3) Opportunities are offered by the South African Native College at Fort Hare, Alice, Cape Province, for all the training required in the line of Teaching and the Ministry and University degrees of B.A. and M.A. But in Law there is no choice except private study. In medicine it has been discovered by the Loram Committee appointed by the Government to 'inquire into the training of Natives in medicine and public health' that the medical needs of the South African Natives will not be satisfied until we have something like nine hundred Native qualified doctors. The Natives at present, compelled by existing circumstances, are still obliged to go to Edinburgh or elsewhere overseas at a prohibitive expense to secure their training in medicine.

Discussion: Mr. J. RHEINALLT JONES, Canon PARKER.

(e) Dr. XUMA.—*Medical Training and the Bantu.*

Thursday, August 1.

EDUCATION AND INDUSTRY.

(a) Prof. F. CLARKE.—*Apprenticeship and School.*

Object of paper not to traverse the whole field, but to raise certain specific questions and to indicate ways in which South African experience may help in elucidation:—

(i) Relation of organised industry to technical school training of apprentices.

(ii) Adjustment of technical school provision to:—

(a) Immediate demands of industry.

(b) Wider needs of young worker as member of producing group and as citizen.

South African Apprenticeship Act.

Proceeds on two main principles:—

(a) Acceptance of apprenticeship as well-defined form of status in a producing system—gives priority to educational (training) considerations over industrial. Hence, its scheme provides a standard for conditions of juvenile employment capable of wide and varied application. Public and other bodies concerned with juveniles in industry all tend to apply it even where the Act itself does not operate.

(b) Autonomy of each organised industry in control of its apprentices under the Act.

Technical Education.

Peculiar social and economic conditions in South Africa as demanding high degree of productive efficiency, primarily in European workers and ultimately in coloured and native workers also. Virtual limitation of operation of Act at present to European section of population.

*Difficulties.*1. *Administrative.*

(a) Independent control of primary and secondary education by Provinces.

(b) Recent decision transferring control of all 'vocational' education to Union. No organic relation between this and Provincial primary and secondary system.

2. *Industrial.*

Limited local field of most apprenticeship Committees. Yet Act empowers them to recommend to Minister (Labour) the number and nature of technical classes to be attended by apprentices. Results in great diversity of claims on Union Education Department for technical school provision. Steps taken to meet this (Central Advisory Committee on courses and syllabuses).

Co-operation of Technical School with Industry.

1. Administrative centralisation of (a) Technical education under Union Minister ; and (b) Labour organisation under Minister of Labour, avoids some of the difficulties met with elsewhere.

2. Organisation of industrial personnel under Conciliation Act and Apprenticeship Act facilitates co-operation with education and serves to promote better understanding by Industry of aims and methods of technical education. Lead given by Government as employer in this respect.

3. Supreme need for a worked-out 'philosophy' of education from Industry itself. Danger of the imposition upon industry of the formal and traditional conceptions of 'scholastic' education. Illustration from marked distaste of technical school pupils for so-called 'cultural subjects' and strong preference for 'trade subjects.' Whole conception of 'subjects' as derived from pedagogic tradition of the past needs to undergo drastic revision. Impossible to define proper place of public education authority in technical education until organised industry has come to full consciousness of its own educational need in relation to the need of the community as a whole.

(b) *Mr. G. FLETCHER.—Some Essays in Education for Industry.*

At the 1905 Meeting of the Association in Cape Town, the author read a paper on 'Technical Education in a New Country.' In the sphere of technical education both Ireland and South Africa might fairly be regarded as 'new' at this period. But the lapse of nearly a quarter of a century has seen noteworthy developments in both countries, and this seems a fitting occasion on which to compare notes on the progress made and difficulties experienced by those engaged in work of national—even international—importance. Such a comparison should be especially fruitful between two countries which, in the field of technical education, have many points in common. In both the staple industry is agriculture, but a curriculum of agricultural education suited to one country would prove unsuitable to the other. South Africa is a growing country, and the trend of movement is towards the land. In Ireland it is away from the land. The population has fallen by emigration from over eight millions in 1840 to less than half, and is still falling—happily at a lower rate—and this exodus is mainly from agricultural areas. Hence it is that a form of education exclusively agricultural in rural areas, must leave a large proportion of the people unfit to earn a living in towns, except by hard manual labour.

The first decade of the operations of the Department of Agriculture and Technical Instruction for Ireland was marked by a multiplication of Technical Schools, but these scarcely touched the needs of rural areas and a comprehensive system of 'itinerant' teaching with 'Winter Schools' of Agriculture was adopted. This teaching comprised courses of instruction—varying from six weeks to three months or more—in Manual Instruction in Wood, Building Construction and, later, in Commercial subjects, with Domestic Economy for women. A comprehensive Scheme for the training of teachers in these subjects was adopted.

This work in rural areas was supplemented by the encouragement of rural industries for which Ireland was renowned. There were numerous small industries—lace and crochet, 'sprigging' and other forms of embroidery, hand-loom woollens, hosiery and the like, and these afforded a useful supplement to the income of the small farmer. A large amount of public money was expended in the encouragement of these, but they have gone backward. Lace and crochet making has suffered from

the vagaries of fashion and the inevitable machine. Sprigging has passed almost wholly on to the Swiss machine (which we introduced into the North of Ireland with success), while the hand-loom woollens are rapidly following hand-loom linens into the factory. This is much to be regretted, and I think we should conserve home industries as far as possible on account of their educational value, though they afford no solution of our industrial problems. The whole tendency of industry to-day is away from the 'craftsman' and towards the efficient machine and mass production. The Educational Administrator must re-orient himself.

Our task would be comparatively simple if we could ascertain for what avocation we were training our pupils, but it is usually quite impossible to do this during the Primary School Course, and in any case I think it is unsound to modify the Primary curriculum because of any consideration of this kind, although I would insist on three subjects as 'essential' in such a curriculum, namely, (1) Manual Instruction in Wood and Metal, (2) Drawing, and (3) Elementary Experimental Science. For those who have to follow a 'trade' the years 14+ to 16+ should be spent in a Continuation School in which the curriculum should be designed with a view to such avocations. The advantages of management of such schools by local authorities are obvious, but the character of the curriculum should be the work of a Central Authority—acting under the advice of industrialists.

The provision of such schools to meet the needs of a growing population is clearly a matter of time. In Ireland, where the population was not growing and funds were not available, it was endeavoured to meet the need, as far as might be, by scholarships and every type was in turn employed, namely:—

1. Scholarships from Primary to Secondary Schools.
2. Scholarships from Primary Schools tenable during apprenticeship with attendance at Technical Schools.
3. Scholarships from works to higher technological institutions (for training managers and foremen).
4. Scholarships from Secondary Schools to higher Art and Technical Institutions.

(A consideration of some of the results of these experiments and of a scheme of training in the works. The attitude of schools, parents and employers.)

The changes which are taking place in the character of industrial undertakings involve a change in the training of our industrial leaders. There should be:—

(a) Specific training in the higher branches of Physical and Chemical Science including research work.

(b) Training in Business Organisation, and

(c) Training in Salesmanship.

(The work of the Department of Scientific and Industrial Research.)

(c) Dr. S. F. N. GIE.—*Vocational versus other Education in South Africa.*

(d) Mr. W. M. HELLER.—*Education for Employment.*

British secondary schools, being the lineal descendants of the 'Latin' or 'Grammar' schools, have produced a race of schoolmasters distrustful of vocational education. 'Cultural' education became synonymous with classical and literary studies.

Times have changed; the schoolmaster has been forced to broaden his curriculum and to modify his conception of culture. Improved aims and methods have to be negated by the growing influence of external examinations.

Indirectly, all education is a preparation for the employment of our working and leisure hours. In the special sense vocational education applies to the two years immediately preceding employment. A deliberate effort to establish standards of conduct and work should permeate all forms of education.

In the primary school the assumption that the three R's provide an all-sufficient equipment is a most dangerous fallacy. The young child craves for general knowledge based upon his own experience and especially for manual occupations.

At twelve years of age a definite change in the aims and methods of instruction becomes necessary. Those intended for professions pass to the secondary school, but the majority leaving school at or before 16 should enter a whole time vocational secondary school. These two types differ in outlook, curriculum and methods.

The vocational school will provide an education for employment; it will have an

atmosphere and discipline different from both the primary and secondary school. Pupils must be led to regard themselves as students responsible for their own success. The curriculum will have a strongly practical bias, and must include much handwork and subjects selected from the following :—

1. Mother tongue. 2. History and Geography. 3. Practical mathematics. 4. General and Rural and Domestic science. 5. Drawing. 6. Handwork. 7. Principles of accounts. 8. Citizenship. 9. Physical culture and Hygiene. 10. Choral music.

Four principal types are suggested :—

- (a) Junior Rural School.
- (b) Junior Technical School.
- (c) Junior Commercial School.
- (d) Junior Housecraft School.

To ensure that the special purpose of such schools controls instruction, there must be complete freedom from external examination.

The majority of secondary pupils leave school at 16, and are educationally 'in the air'; they should pass not later than 14 to a vocational school.

The staffing of vocational continuation and secondary schools presents difficulties; the secondary and technical teachers have much to learn. Manual training and trade science should be taught by men who have practised the trade.

Extensive experiments in whole-time pre-apprenticeship training have been carried out in the Dublin Technical schools for about twenty different trades.

Vocational secondary schools in large centres have proved a success.

Boys and girls leave school having satisfied examination tests, but unchanged in standards and character. A mechanical routine of preparation for examination is accompanied by a vain hope that these other purposes in education will be achieved without deliberate effort.

A greater concentration upon the demands that employment will make upon the knowledge and wisdom of the pupil may do much to remedy the aimlessness that has crept into many schools.

Discussion : Sir THOMAS HOLLAND, K.C.S.I., F.R.S. ; Sir RICHARD GREGORY.

Friday, August 2.

Joint Meeting with Section E on *The Teaching of Geography*. (See p. 351.)

SECTION M.—AGRICULTURE.

For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 430.)

CAPE TOWN.

Tuesday, July 23.

Discussion on SOIL FERTILITY AND ITS CONTROL. (Opened by Sir JOHN RUSSELL, who will deal with Factors determining Soil Fertility, with special reference to Plant Nutrition; followed by Prof. I. DE V. MALHERBE, Mr. C. G. T. MORISON, Mr. T. D. HALL and Prof. G. W. ROBINSON.)

Sir JOHN RUSSELL, F.R.S.—A fertile soil is one which satisfies all the conditions of plant growth, supplying adequately plant nutrients, water, warmth, air for the roots, space for the roots, free from undesirable substances or harmful reaction. These factors are closely linked, especially plant nutrients, water supply and soil reaction; and also soil water, soil temperature, and air supply.

The supply of plant nutrients affects crop production in two ways. Other conditions being favourable, the amount of plant growth is increased with increasing

supply of nutrients up to a certain point. The relationship is not simple : it can be expressed by two factors, one being the minimal amount in the crop of the particular nutrient, and the other the supply of the nutrient already present in the unmanured soil. Some degree of proportionality between the various nutrients is necessary, but there is no evidence that the ratios are narrow.

These relationships are much affected by the water supply. In general, nutrients are most effective when there is a good water supply, and the water is most effective when there is a good nutrient supply. A good water supply thus economises the nutrients, and conversely a good nutrient supply economises water. For fruit the relationships are somewhat different, fruiting and growth being in some ways antagonistic. These relationships are important in irrigation practice.

The second way in which nutrients affect the plant is to change its composition, habit of growth, and response to external conditions, including the attacks of insect and fungus pests.

So long as the proportion between the different nutrients is such as to give a normal plant, variations in the total amounts have but little effect on composition or habit of growth ; the individual plants may be larger or smaller, but the material of the plant is not much affected. As soon, however, as the proportion of any one element falls too low, certain characteristic effects are produced on the plant which may profoundly alter its reaction to external conditions, and its chemical composition, and therefore its agricultural value.

In certain conditions any of the elements may thus be in deficiency. Considerable investigation has been made to discover the effects of these deficiencies, and also their symptoms, so that the agricultural expert might be in a position to recognise them. Large excess of certain of the elements relative to the others also produces characteristic effects, which are being studied.

In humid regions deficiency of nitrogen relative to the other elements is common, the result of the ready solubility of the soil nitrates. This reduces the rate of growth and the total amount of growth, but otherwise has little effect on the composition or character of the plant. Nitrogen deficiency is closely linked with the organic matter content and the microbiological activity of the soil. In the writer's experience it does not occur in dry regions.

Phosphate deficiency may arise anywhere, but especially on soils derived from rocks containing little or no animal remains. It reduces the root activity of plants and the tillering of cereals, and brings about certain chemical changes profoundly affecting the quality of the produce. Phosphate starved grass is innutritious to animals, inducing phosphate deficiency diseases which have been much studied by Theiler, du Toit and Green in South Africa.

Iron deficiency is perhaps more common than is usually recognised. B. C. Aston first found it in certain New Zealand soils and traced to it a persistent anæmia of cattle, from which they suffered greatly and finally died. This was in a wet region on somewhat acid soil sufficiently light to allow of ready leaching out of the iron from the surface layer. A similar disease is said to occur elsewhere in similar conditions and may have the same cause. Unfortunately no easily recognisable symptoms in the vegetation have been observed, but analysis of the ash at once reveals the deficiency of iron. A like deficiency may occur in dry regions : possibly some of the fertilising effect of sulphur in these conditions may arise from an effect on the iron compounds in the soil.

To manganese deficiency has been attributed a disease of oats, and to magnesium deficiency a chlorosis of tobacco.

Potassium deficiency is usually found only in relation to nitrogen excess. When the ratio of nitrogen to potassium becomes large the plant is considerably altered : its leaves become very dark green, liable to die in discoloured patches, liable also to attack by certain fungi ; the percentage of starch or sugar in the storage organs falls off, and the percentage of nitrogen compounds correspondingly increases. The grain of barley suffers in malting quality, the tubers of potatoes suffer in cooking quality, and the roots of sugar beet not only contain less sugar, but yield a more impure juice.

Calcium deficiency is in a different category, being closely linked up with the exchangeable bases in the soil, and with the whole body of its physical and chemical properties. It is most liable to occur in wet regions, where it results in an acid soil. It may occur in dry regions, however, especially where sodium chloride is present, and the sodium has displaced some of the calcium. When this replacement has proceeded beyond a certain stage the properties of the soil are drastically altered,

making it unsuitable for many agricultural crops. This change is of great importance in irrigation areas, and it is an important factor in the evil effects of over-watering.

Mr. C. G. T. MORISON.—*Some Factors controlling Soil Fertility.*

Variations in soil composition—the soil as a succession of changing horizons—change in horizon character with season—the content in exchangeable bases, and in degree of saturation of definite horizons varies through the year. The effect of loss of water upon the H ion content of soil suspensions, and upon the exchangeable base content of the soil. Possible effect of de-hydration upon soil fertility.

Physical Factors and their Control. (Dr. B. A. KEEN, Dr. W. G. OGG and Prof. N. M. COMBER.)

The soil moisture is undoubtedly the most important physical factor in plant growth. Measures of control seek as far as possible to maintain it at its optimum value, which lies between the deleterious extremes of excess (waterlogging) and deficiency (drought).

Methods of soil treatment to encourage rapid drainage of excess water are quite well understood, but there is still very considerable divergence of opinion as to how far it is possible by appropriate methods of cultivation to conserve soil moisture in regions of deficient rainfall. It is frequently stated that the preservation of a mulch of dried soil is an effective means of conserving from evaporation the water in the soil below the mulch. On the other hand, extensive work on the influence of moisture on crop production in the Great Plains area of America has led to the conclusion that the loss from a mulched surface is practically the same as from an unmulched one; the effect of cultivation is to prevent weed growth and hence transpiration losses, and the mulch is, in fact, only incidental. The theory on which the supposed action of a mulch is based likens the soil to a mass of fine capillary tubes up which water can ascend from the free water table to the surface. The mulch is supposed to break these channels, and thus to prevent water in liquid form from rising higher than the bottom of the mulch. Work at Rothamsted and elsewhere has shown this idea to be incorrect and has also demonstrated that the distance to which water can ascend above the free-water table is much less than that predicted by the laws of capillary rise.

Wednesday, July 24.

Joint Discussion with Section F (*q.v.*) on *The Problem of stabilising Agricultural Prices, with special reference to Control Boards, Equalisation Funds and other methods of Price Regulation.*

Thursday, July 25.

Discussion on SOUTH AFRICAN WOOLS AND WOOL GROWING :

(a) **Dr. S. G. BARKER.**—*The Scientific Measurement of the Attributes of the Wool Fibre and their Importance as a Link between Producer and Manufacturer, with particular reference to South African Wools.*

The measurement of fibre characteristics is dependent largely on the proper design of physical instruments for carrying out the work. The relationship of wool quality to spinning power can only be defined when these characteristics are being properly analysed. Apparatus is described for the determination of cross-sectional area, crimp, fibre length, rate of growth, &c. The relationship between these attributes and actual manufacturing conditions is discussed, and the relative importance and development of these in South African wools is described. Mathematical relationship between crimp and fibre thickness, as well as the development of international standard methods of wool examination, is investigated.

(b) Prof. A. F. BARKER.—*Wool Manufacturing Requirements and their bearing on South African Wool-growing.*

The introduction of synthetic fibres, the competition to be anticipated from new wool-producing countries, and the extraordinary influence of "fashion" make it more necessary than ever for wool-growers, if possible, to adjust their productions to the present and prospective requirements of the wool-manufacturing industry.

Review of the history of the development of wool-growing countries—the interaction between Australia and Yorkshire in the first half of the 19th century; the response of Yorkshire to New Zealand's mutton (crossbred) wools in the second half of the 19th century; the inter-action between South America and the Continental wool manufacturing countries, &c., &c.

The limits within which each wool-growing country must work incident upon the adjustment of race to environment.

The three characteristic races of sheep—Merino, British and Fat-tailed or Fat Rump. The remarkable evolution of the Merino sheep—Rambouillet, Vermont and Hornless strains. The gregarious nature of the Merino—its advantages and disadvantages. Other racial characteristics and how advantage may be taken of them—Camden Park and German Merinos and "Faced-cloths." The British breeds, their non-gregarious nature and other racial characteristics. How advantage may be taken of these. Merino and British sheep contrasted, and how racial characteristics may be made the basis of selection along the most promising lines.

The respective possibilities of working upon Mendelian characters and upon mass selection. Wood's work upon horns and fibre inheritance, and Dry's upon colour. The colour problem in Herdwicks, Downs and Wensleydales. Mass selection and the evolution of the heavy-fleece and the wool-mutton sheep in Australia. The limitations and combinations of both systems. Australia's experiences with reference to the heavy-fleece type of sheep—quantity *v.* quality of wool. The value of the study of genetics.

The present and prospective requirements of the British and Continental wool-manufacturing industries and the possibilities of South African wools fulfilling these requirements:—

1st. The problem of fine wool growing under satisfactory economic conditions and the promise of the future along this particular line. Fabric "handle."

2nd. Colour inheritance and the problem of snow-white Cape wools: Lustre.

3rd. The felting property of wools and the peculiarities of inheritance of this wool characteristic.

4th. The problem of the "Kemp": its elimination.

5th. The problem of the uniform growth of the wool fibre and of the best types for prospective requirements.

6th. The problem of the uniform growth of the wool staple and of the correct shape of staple.

7th. Yields and tearage—race or environment characteristics?

8th. The adjustment of race to environment in South Africa with all these points in view.

Field work in sheep-breeding and wool-growing.

The advantages of collaboration between sheep-breeder and wool-manufacturer.

(c) Prof. J. E. DUERDEN.—*Recent Research with reference to South African Wools.*

The ultimate object of the research is to advance still further the wool production of the Union by improved genetical and pastoral conditions. Before this can be carried out on a scientific basis it is necessary that standards should be available relating to the various wool characteristics, such as fibre thickness, density, elasticity, pliability and yield, whereby reliable comparisons can be instituted. Hitherto, attention has been mainly directed to fibre thickness standards, and lately a series has been issued for all merino grease wools ranging from 56's to 150's quality, based both on the number of crimps per inch and on the mean thickness. The two are shown to have a high degree of correlation, but anomalies occur in impoverished wools and in wools growing over folds and pleats. A scale has been designed for the ready estimation of the crimps.

The standards have been founded on uniform representative samples of the

different qualities of South African grease wools, and are now being applied to commercial bulk samples, which are always mixtures. They have also been applied to wools from various parts of the world and to tops, and the results suggest that a common basis of comparison may be arrived at for the raw wool production of the world and for the early stages of its manufacture.

(d) Dr. J. E. NICHOLS.—*Some Aspects of Empire Wool Production.*

(e) Discussion.

Friday, July 26.

Mr. G. FRECHEVILLE.—*Crop Rotations and the Maintenance of Soil Fertility.*

Mrs. N. L. ALCOCK.—*The International Aspect of Plant Diseases.*

Each country must be responsible for the health of its exports. There are two methods of safeguarding Plant Trade :—1st. The Method of *Embargo*. In a general form this kills all trade. Each country will exclude certain specific diseases. 2nd. Some form of *health certificate*.

Great Britain has chosen the latter method and realises that, to make it effective it includes :—

- (a) Safeguarding imports—care must be taken to prevent the entrance of disease.
- (b) Insisting on a reasonable standard of health in the country, in growing crops, nurseries, &c. ; inspection in the field for certain crops such as potatoes.
- (c) Knowledge of where disease exists entailing a general disease survey.
- (d) Inspection of Exports by competent Mycologists.

Safeguarding Imports.

Imports are in two categories (certificated).

(a) Imports which are likely to prove dangerous on account of the fact that they come from countries where the flora and fauna are different from our own, or because they are known to carry some special pest not already in Great Britain.

(b) Imports from countries where the flora and fauna are identical : the diseases and pests are exactly the same as in Great Britain. These are less dangerous.

Imports in category (a).—These plants are re-examined and in the majority of cases are looked at a second time by competent inspectors during the growing season.

Imports in category (b).—If these carry a certificate ensuring a high standard of health it is merely necessary to carry out sample inspection to ensure the certificate is maintaining its declared standard.

There remains of course, a group c. Plants without a certificate. These are always inspected and are treated additionally in accordance with the needs of the case.

Plants for export obviously have to be treated in accordance with the rules of the country to which they are going. The value of a Health Certificate must depend on the competence of those giving it. In the case of large quantities the sampling method must be employed. The careful examination of a sample is better than the casual inspection of the whole.

If given by competent men the value of a Health Certificate will lie, not so much at the moment of export, as in the well-known fact that inspection and certification tend to raise the general standard of plant products all along the line. The best growers in Great Britain are the best in the world. The effect of a good Plant Disease Service tends to approximate the less good to the standard of the best.

It seems obvious that the ideal to be striven for is an agreed imperial system of inspection and certification which will be standardised in its basic features, but which will be sufficiently flexible to admit of modifications to suit varying regional needs.

Dr. WINIFRED BRENCHLEY.—*The Dormancy of Weed Seeds in the Soil as affected by Cultivation and Fallowing.*

Numerical estimations are being made of the effect of cultivation and fallowing on the number of viable weed seeds in the soil of Broadbalk permanent wheat field, Rothamsted. Counts are made of the number of seedlings derived from numerous measured samples taken annually after harvest. Excluding poppy, the number of living seeds on unfallowed land ranged from 27 to 62 millions per acre, according to

the manuring, and poppies rose to over 250 millions per acre with complete fertilisers. Some weeds are unaffected by the manuring, but others are definitely encouraged or discouraged by various combinations of manures. The response of different species of weeds to two years' consecutive fallow varies considerably. Some species, as *Alopecurus agrestis* (black bent) and *Polygonum aviculare* (knotgrass) are almost eliminated, whereas *Papaver spp.* (poppy) is only reduced to about 46 per cent. of the original number, and a few others are very little affected. This is due to the varying lengths of time that buried seeds naturally remain dormant even when they are brought under conditions favourable for germination. Consequently, fallowing might prove economic for heavy infestations of some weeds as black bent, but for poppy and others the clearance would not be good enough to justify the expense.

The times of maximum germination of weed seeds show a marked periodicity, most species having a strong preference for starting into growth in either the autumn or the winter quarter, comparatively few coming up in the spring or summer. Land should therefore be broken up as soon as possible after harvest and kept on the move in order to obtain the maximum reduction of buried weed seeds, whether the land is to be cropped or kept under fallow. The experiments are being continued to determine the after-effects of fallowing when the field is back under crop.

PRETORIA.

Wednesday, July 31.

Discussion on METHODS OF SOIL INVESTIGATIONS IN FIELD AND LABORATORY.

(a) Soil Classification :

- (i) *Field Methods*.—Prof. G. W. ROBINSON (Agricultural Soils), Mr. A. STEAD, Mr. C. G. T. MORISON (Forest Soils).

Prof. G. W. ROBINSON.—*Soil Surveys and Soil Classification*.

Some kind of classification must accompany every type of soil survey. Considerable attention has been devoted to the formulation of systems of classification which shall embrace soils from all parts of the world. Such systems have been proposed by Glinka, Lang, Ramann and others. Marbut has recently outlined a scheme which has the advantage that it is sufficiently elastic to include new types yet to be discovered.

In the survey of a new country, however, the place of its soils in a world system of classification does not call for immediate attention. The most important task is to recognise what are the significant types, and to arrive at a classification which is valid for the country in question. In arriving at this classification, two considerations should be borne in mind. Firstly, the classification should be based on the soil itself and not on the factors influencing soil formation. Where, however, a close correspondence can be shown between the character of the soil and one of these factors, e.g. geology, or topography, such factors may reasonably be used as aids in mapping. Secondly, the unit of study should be the complete soil profile and not simply the surface soil.

Generally speaking, the main types of soil in any country can be recognised by field observations. Laboratory examination serves to give quantitative significance to type descriptions and may also help in the final subdivision of areas marked for intensive survey.

When the soils of a country have been properly arranged into types among themselves, it will be possible to consider their place in a world classification. The accumulation of information as to new soil types must necessarily modify schemes of classification already proposed.

Mr. C. G. T. MORISON.—Records required in surveys of forest soils—extensive and intensive surveys. Vegetation characters—permanence and depth of leaf litter—depth of profile observations—the development of aerial surveys.

- (ii) *Laboratory Methods: Chemical Analyses*.—Mr. A. STEAD, Dr. W. G. OGG, and Dr. M. S. DU TOIT.

Mr. A. STEAD.—Chemical analysis is used for three main purposes, namely :—

1. For ascertaining manurial needs.
2. For assisting in checking soil types in survey work.
3. For investigating the constitution of the soil.

Much of the adverse criticism levelled at soil analysis is probably due to a wrong perspective. While it is fully understandable that chemical analysis may be very misleading when applied for the purpose of determining the manurial needs of long and intensively cultivated soils, so far as this country is concerned, there is not the least doubt that poor and good virgin soils are reliably indicated as the result of chemical analysis.

The value of chemical analysis in determining soil types is undoubted and need not be stressed; neither need its indispensableness in investigating the soil as soil. The trouble about chemical analysis of the soil, however, is its laboriousness and expense. Reasonably accurate and very quick methods of analysis are badly needed to enable the chemical investigation of the soil to be very much extended. We have devoted much attention to such methods with gratifying results, as will be detailed by Dr. v. Zyl of my staff. I would, however, refer especially to the need of a fairly accurate micro method for the direct determination of base-exchange sodium. This would put one in a favourable position to ascertain by laboratory experiment what change the physical condition of the soil is likely to undergo as the result of continuous irrigation with the particular water or waters that are available to irrigate it. The inability always to prophesy what will be the result of irrigating arid and semi-arid soils is one of the principal handicaps confronting the soil survey investigator.

Dr. W. G. OGG.—*The Value of Rapid Methods in the Chemical Examination of Soils.*

There are certain lines of soil investigation which call for very numerous chemical analyses, and in view of the lengthy and laborious nature of some of these analyses it may be useful to consider the possibility of developing more rapid methods. The need for something of the kind is particularly apparent in survey and advisory work.

In soil survey work, chemical analyses are useful in establishing the type to which a soil belongs, in throwing light on its properties and in checking the boundaries established by field workers between types. A soil type which may be incapable of further sub-division on field characters, may show a considerable range in chemical properties, and it is usually necessary to carry out a large number of analyses in order to determine what is normal for the type and how it may vary. In many cases, at any rate for a beginning, a large number of approximate tests would be more useful than a small number carried out with extreme accuracy.

The same is true in advisory work. To carry out analyses by the present official methods requires a considerable amount of time and the accuracy of the results obtained is rather out of proportion to our ability to interpret and apply them. It would be sufficient in many cases to be able to determine whether the amount of the constituent in question was very low, low, medium, high or extremely high.

It is, of course, very important to recognise the limits of accuracy of such methods and not to push their interpretations too far.

There are already in use several tests which can be carried out rapidly and which have proved of considerable value. For example, in studying questions of soil acidity, such tests as those suggested by Truog and Comber, and the determination of hydrogen ion concentration provide useful data, and recently a rapid electrometric method for measuring 'Lime Requirements' has been published by Hardy & Lewis.

An extensive field to field pH survey has been carried out in the South-East of Scotland. The admittedly inadequate information obtained from the pH figures has been supplemented by other tests, such as the determination of exchangeable calcium, carried out on a limited number of samples from the various areas surveyed. The results obtained give interesting information on the intensity and distribution of acidity in the districts studied and indicate the places most in need of lime. The rapidity with which pH measurements can be carried out has made this investigation possible on a much larger scale than would otherwise have been the case. Attempts have also been made to devise rapid tests for phosphate, potash and nitrogen. Purely qualitative tests are described by T. B. Wood in his 'Course of Practical Work in Agricultural Chemistry'; rapid quantitative tests are given in Hilgard's 'Soils'; and an

attempt to devise a micro-chemical field method for the estimation of phosphates has been made by Spurway. These by no means exhaust the list, but will serve as examples. Perhaps further advances can be made along the lines of shortening the preliminary treatment, measuring the volume of precipitates and introducing micro-chemical and colorimetric methods. These purely chemical extractions may or may not throw light on the availability to the plant of the materials extracted. Probably this will require to be standardised by means of pot trials and field experiments or tests such as those of Neubauer and Mitcherlich which make use of the actual plant.

(b) *Physical Analyses*.—Dr. B. A. KEEN, Mr. J. R. H. COUTTS (Single Value Determination on South African Soils), Dr. J. P. VAN ZYL, Dr. B. DE C. MARCHAND, Dr. M. S. DU TOIT, Prof. N. M. COMBER, and Dr. SINCLAIR.

Dr. B. A. KEEN.—An examination is made of a number of physical properties of Natal soils, and an attempt made to determine which of these are likely to be most useful for purposes of general classification of large numbers of soil samples. It is suggested that the sticky point, or the loss on ignition, and the Keen-Raczkowski box data might well be adopted for this purpose. The moisture content of a soil in equilibrium with an atmosphere of 50 per cent. relative humidity is also worth consideration. In order to obtain an estimate of the organic matter in the soil, it is necessary to determine the loss on ignition of the soil after treatment with hydrogen peroxide (I_p) as well as on the original soil (I_o). Then, $(I_o - I_p) \frac{4}{3}$ gives a fair estimate of the organic matter.

Prof. N. M. COMBER.—*The Policy and Purpose of Soil Analysis*.

It is an inevitable and natural consequence of the historical origin of scientific soil studies that they have all along been pursued in close association with the industry of farming. It is only in quite recent years that there have been signs of a general tendency to segregate the scientific study of the soil. Soil studies are, therefore, very largely in the position that geological studies would have been in if geology had been studied almost exclusively in the interests of an industry, e.g. mining. The principal studies in soil analysis have been directed towards recommendations for soil management. It cannot be claimed, however, at any rate so far as Great Britain is concerned, that these analytical studies have succeeded in doing anything like what was originally hoped for and aimed at, in facilitating the business of crop husbandry. Soil analysis has played but a small part in the introduction and development of the use of artificial fertilisers. Indeed, if soil analysis and its consequences were eliminated from the developments in the use of fertilisers during the last three-quarters of a century, it is doubtful whether the position would be very much behind what it is. If we face the present outcome of soil analysis with proper perspective we must admit that its most important results have been to reveal the existence of, and to some extent to explain the nature of, great complications in soil structure. It seems very desirable from every point of view that this position should be faithfully admitted, and that we should openly abandon the continued pursuit of this work on the main grounds of its immediate utilitarian service to industry. If this is done a greater freedom and a greater scope for individual initiative will result which in the long run must be to the advantage of everyone concerned with the soil from whatever point of view. Anyone who has been concerned with soil analysis for any number of years has entertained the hope that so far as their immediate utilitarian value is concerned we might gradually get away from purely arbitrary methods of analysis. There is, however, at any rate in Europe, a growing tendency to increase rather than to reduce these arbitrary methods; a tendency which is finding its expression in an increasing amount of co-operative work designed with a view to fixing in all their detail, international methods of analysis. It seems worth while to call in question the wisdom of this and to suggest that the time has not yet come, and that a great deal more investigation into the constitution of the soil must be made before the time does come, when international methods of soil analysis can reasonably be standardised in this kind of way.

Thursday, August 1.

Presidential Address by Sir ROBERT GREIG on *Agriculture and the Empire* (see p. 230). Followed by Discussion. (Colonel E. M. WILLIAMS, Sir DANIEL HALL, Major WALTER ELLIOT, M.P., and Mr. J. A. MANSON.)

Friday, August 2.

Discussion on *The Mineral Aspects of Pasture Nutrition in relation to the Livestock Industry*. (Major WALTER ELLIOT, M.P.; Mr. A. D. HUSBAND; Dr. P. J. DU TOIT.)

Mr. R. A. DYER.—*Veld Experiments on the Amatola Mountains and their Importance with Reference to Soil Erosion*.

Mr. A. STEAD.—*The Deterioration of Pineapple Soils*.

Dr. G. DE KOCK.—*The Spleen in Ruminants and Equines*.

Mr. R. R. STAPLES.—*Studies in Pasture Management*.

Monday, August 5.

Mr. R. J. THOMPSON, C.B.—*The World Agricultural Census*.

During recent years there have been great developments in the collection of agricultural statistics—the proposed World Census is an effort to speed up the process. The idea of a periodical census of agriculture is not new; the new element in the proposal put forward by the International Institute of Agriculture lies in the attempt to get a census taken in all countries at the same time. The plan has been discussed with statistical representatives of most of the Governments of the world, and general agreement has been reached as to broad principles. Its acceptance has been helped by personal contact, at various conferences between officers concerned and by the efforts of the director of the census project who has toured the world and interviewed the responsible authorities in every country.

Description of the plan of the census.

Principal questions limited to absolute minimum so as to enable all countries to participate. Methods of taking a census. Employment of enumerators. Limitations due to lack of knowledge on the part of occupier. Ascertainment of production either by direct inquiry from occupiers or by estimation by experts.

A census taken at intervals is only a foundation. Knowledge of supply of food-stuffs and raw materials of vital importance in international trade, but to be of real value must be up to date. Census therefore needs to be supplemented by periodical crop reporting system, but it provides foundation on which to build and a means of controlling estimates. Census also valuable for economic purposes in providing information as to progress of agriculture as part of the economic life of a country. Results will provide wide field for investigation.

Discussion on *Cost of Production Studies in Agriculture*. (Mr. J. A. VENN, Dr. A. G. RUSTON, etc.).

Mr. J. A. VENN.—*Cost of Production Studies in Agriculture.*

Despite growing competition from the more widely flung, but less complete, investigational system represented by the survey method, cost accounting has, during the last decade, made considerable progress in many countries of the world. The problems associated with its execution are threefold in character: (a) statistical, (b) economic, and (c) accounting. Uniformity of technique in regard to book-keeping principles has generally been looked upon as of paramount importance, and in consequence too little attention seems to have been paid to the statistical factors involved, both in preliminary selection of the sample and in presentation of results. Thus the necessarily small number of examples dealt with in any voluntary scheme of co-operation may, on human and psychological grounds, result in bias towards a standard of management or of productivity above the normal or, conversely, there may be present too many undertakings labouring under financial difficulties, for reluctance to supply information on the part of persons securing abnormal profits, together with willingness to do so on the part of those losing money, must always be taken into account. As in such inquiries random sampling is, from the nature of the case, out of the question, close culling is imperative. Again, the chronological factor is, at least in Western Europe, of great importance, for results based on a shorter period than the complete normal rotation (generally of four years) are almost valueless, for introduction of the necessary allocations can vitiate figures relating to individual years. When amalgamating results the alternatives presented in the adoption of the 'simple' or of 'weighted' averages are far-reaching in effect. At what numerical stage, and within what density and type of distribution, should the 'simple' be substituted for the 'weighted' figure? For example, in connection with an inquiry into sugar beet costs of production, sugar-content based on the former figure, when converted into money equivalent and multiplied by the simple average yield, gave a result which differed only by 1s. 1½d. per acre from the actual sum paid, but when weights were introduced this divergence became 15s. 7½d. In effect it will generally be found that statistical factors outweigh the great majority of accounting adjustments.

Economically the slow processes of nature ('inelasticity of supply') render difficult the investigation of alternative procedures and, as has recently been stated, 'the confusion between prime and supplementary costs, the lag in production, the allocation of expenditure between capital and revenue account, the differences between farmers and farms . . . make costing more difficult than in other industries.' Classification of types, especially in connection with soil variations, present further difficulties to the investigator, which necessarily result in definitions such as 'soils more light than heavy' *versus* 'soils more heavy than light,' 'mainly beef production' *versus* 'mainly milk,' while the latter may again have to be subdivided into 'mainly wholesale' *versus* 'mainly retail.' Agreement is even lacking in regard to what should constitute the ideal—high farming, maximum employment of labour, profit to the occupier or return to the landlord?

In the field of pure accountancy the only two items which can seriously affect results are (a) remuneration to the farmer as manager or worker, and (b) interest on capital employed in the undertaking. The former tends to become an optional charge relegated to a separate column, the latter, widely recognised in industrial cost accounts, is, in agricultural practice, with the exception of borrowed sums, in some countries included and in others rejected. Such allocations as those involved in the valuation of home produce consumed on the farm, residual manurial values, the position of fallow crops, and the treatment of overhead charges, can be demonstrated to be of minor importance in the economy of the farm as a unit. Methods of valuation, once established, have little effect on returns.

If close personal touch is maintained with those co-operating in such inquiries (entire reliance upon information contained in post-delivered forms renders the work nugatory) and due consideration is given to the above statistical and economic factors, cost of production studies can achieve satisfactory results both in general terms and also in relation to individual products. That, in these circumstances, close approximation—statistical and economic—to the normal can be achieved by even a small sample, this table illustrates. (*Report No. 12, Farm Economics Branch, Department of Agriculture, Cambridge University.*)

EASTERN ENGLAND.

	Normal conditions (based on official statistics and 'Census of Production' figures).	Twenty-four Costed Farms.
Capital per acre	£14	£15½
Percentage of permanent grass to total crops and grass	28·9	24·2
Rent per acre.	29s.	27s. 6d.
Density of paid regular workers per 100 acres of crops and grass	3·51	3·53
Density of horned stock per 100 acres of crops and grass	13·0	14·1
Average yield of wheat per acre (cwt.) . . .	17·6	17·7
Average yield of barley per acre (cwt.) . . .	15·0	15·6

When, as in this case, psychological or human influences have been excluded, it will be agreed that deductions based on the results achieved are worthy of close study, as being in all probability typical of conditions ruling throughout the area in question—on the 'modal,' that is to say, rather than on that elusive entity—the 'average' farm.

Studies, often State-inspired, of particular commodities, *e.g.* wheat, milk, sugar-beet, must always make appeal both to Governments (in connection with policy) and to producers, while complete investigations possess more value to the individual farmer and research worker. When based on sound statistical foundations, granted a prolonged life and careful direction, both can produce dependable results; ill-prepared and short-lived, nothing can excel them as material for the manufacture of misleading assumptions and false generalisations.

MEETING OF L'ASSOCIATION FRANÇAISE POUR L'AVANCEMENT
DES SCIENCES : HAVRE 1929.

CONFERENCE OF DELEGATES OF
CORRESPONDING SOCIETIES.

As in 1914, l'Association française pour l'avancement des sciences conveyed through Dr. A. Loir, Director of the Bureau d'Hygiène at Havre, the generous invitation of the French Association for members of the British Association not attending the South African Meeting to attend that of the French Association at Havre (July 25-30, 1929). The invitation, which was gratefully accepted, included the proposal that the Conference of Delegates of Corresponding Societies should meet at Havre. About fifty members of the British Association attended.

At the inaugural meeting, under the presidency of M. le Général G. Perrier, Sir Henry Lyons, F.R.S., spoke on behalf of the British Association as follows :—

M. LE PRÉSIDENT, MESDAMES ET MESSIEURS.

C'est un très grand honneur pour moi d'offrir à votre Association tous les vœux de l'Association britannique pour l'avancement des sciences, et d'exprimer notre reconnaissance pour l'hospitalité montrée à ceux de nos membres qui sont empêchés de se rendre à la réunion dans l'Afrique du Sud.

Ceux de nous qui ont pu profiter de votre amabilité attendent impatiemment de prendre part à vos réunions où les derniers progrès dans toutes les branches des sciences seront discutés. De la discussion jaillit la lumière, et nous ne pouvons que gagner de précieux éclaircissements.

Voilà la seconde fois que l'Association française pour l'avancement des sciences s'est jointe en une fraternité scientifique à l'association sœur. Dans l'occasion précédente en 1914, lorsque l'Association britannique se réunissait en Australie, cet éminent chimiste, feu Sir William Ramsay, occupait la même position que j'ai aujourd'hui. Votre Association se réunissait déjà sous le menace de la grande guerre qui devait, hélas, éclater si tôt. Dans les années qui suivirent des milliers de mes compatriotes goûtèrent hospitalité de cette grande cité—Le Havre—sur le chemin vers le front ; ils se souviennent avec gratitude des jours passés dans votre cité si hospitalière.

Mais il y a dix ans de tout cela.

La demande urgente qui fut faite à la science pendant ces années de lutte n'a pas été la moindre forte influence dans le merveilleux développement de toutes les branches de la science, qui est le phénomène le plus remarquable de notre société actuelle. La Science moderne est essentiellement internationale ; chaque collaborateur doit se maintenir en rapport avec tous ceux dans les autres pays, qui travaillent dans le même champ l'efforts ; et c'est dans de semblables réunions à celle-ci que les relations personnelles, qui sont si nécessaires, peuvent être commencées et maintenues.

J'ai eu la bonne fortune d'être associé pendant les dix dernières années avec votre Président, le Général Georges Perrier, dans le champ international de géodésie. Je reconnais et apprécie hautement son énergie, sa grande habilité scientifique et ses connaissances techniques. Un illustre soldat qui, par sa connaissance profonde en géodésie, et théorique et pratique, a été reconnu par son election comme membre de l'Institut de France ; je ne peux imaginer personne de plus éminemment adapté pour être Président de cette noble Association et pour diriger ses activités.

Au nom du Conseil de l'Association britannique pour l'avancement des sciences, et au nom de tous ses membres, spécialement ceux qui sont ici aujourd'hui recevant votre hospitalité, je souhaite à votre Association et à vous, Monsieur le Président, une réunion pleine de succès.

CONFERENCE OF DELEGATES, FRIDAY, JULY 26, 1929.

At the conference, Dr. F. A. Bather, F.R.S., occupied the chair as president thereof, Mr. T. Sheppard was present as acting-secretary, and Delegates representing fifteen Corresponding Societies of the British Association, and other members of the British and French Associations for the Advancement of Science, to the total number of about eighty, also attended.

Dr. Bather expressed his deep regret that death had deprived the Conference of the presence of Sir George Fordham, who was well known in Havre, and had been appointed to preside over the present meeting. Sir George Fordham had devoted himself generously to the cause of science, and had interested himself for many years in the work of the Conference, his own special interest being in cartography.

The chairman then called upon Mr. T. Sheppard, who voiced the sense of indebtedness to Dr. A. Loir, the local secretary of the Association française for the Havre meeting, which was felt by members of the visiting party from England. He recalled the occasion at the British Association meeting in 1928 upon which the honorary degree of LL.D. of Glasgow University was conferred upon Dr. Loir, and asked Dr. Loir to accept as a present from some of his friends in the British Association a gown signalling this honour. Dr. Loir accepted the gown and expressed his appreciation.

A paper, with lantern illustrations, was read by Mr. E. O. Forster Brown, M.Inst.C.E., on 'Scientific Aspects of the Channel Tunnel,' the subject being approached mainly from the geological and engineering viewpoints. The paper, which emphasised the necessity of ascertaining all possible facts before beginning tunnelling operations, even at very considerable cost, has been published in the *Colliery Guardian*, August 16 and 23, 1929.

A brief discussion followed the paper, and a vote of thanks was then accorded to Mr. Forster Brown.

A written contribution by Prof. P. F. Kendall, F.R.S., on 'The Proposed Tunnel under La Manche,' intended for communication to the Conference, was received, and was published in *The Naturalist* for October 1929 (pp. 327 seqq.), in which also an account of these transactions will be found.

Dr. Bather, addressing Delegates of Corresponding Societies, raised the question of the proper function of the Conference of Delegates, and referred to the frequent difficulty of finding suitable subjects for discussion, bearing directly upon the common interests of local scientific societies of all kinds. He outlined the possibility, which he personally foresaw, of ensuring more complete co-operation of the societies through the agency of the existing regional associations of societies, co-ordinated under the auspices of the Conference of Delegates.

Mr. T. Sheppard explained the co-operation among societies achieved through the medium of the Yorkshire Naturalists' Union, and the publication in *The Naturalist* from month to month of the results obtained by scientific workers. He invited suggestions from delegates for the more effectual working of the Conference.

Reference was here made to Captain Dannreuther's suggestion regarding copyright, already communicated in writing to Mr. Sheppard, and answered by him.

A vote of thanks was accorded to the Association française pour l'avancement des sciences for its hospitable invitation enabling the Conference to take place in Havre.

Before the opening of the meeting of the French Association Sir Henry Lyons laid a wreath on the War Memorial in Havre, in the name of the British Association. General Perrier subsequently laid a wreath on the British War Memorial in the cemetery.

The British colony at Havre entertained the visitors at an evening conversazione.

Sir Henry Lyons and Mr. T. Sheppard were the recipients of silver medals from the French Association in commemoration of their services.

The thanks of the visiting party were conveyed by Sir Henry Lyons to General Perrier, and to Mr. H. Swan, the British Consul.

REFERENCES TO PUBLICATION OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

The names of readers of papers in the Sections (pp. 310-423), as to which publication notes have been supplied, are given below in alphabetical order under each Section.

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* (weekly) during and subsequent to the meeting, in which summaries of a number of papers are published.

It is understood to be the intention of the South African Association for the Advancement of Science to publish in full a number of the papers in the *South African Journal of Science*, but details were not to hand when this Report went to press.

SECTION A.

Aston, Dr. F. W.—Cf. Bakerian Lecture, *Proc. Roy. Soc. A*, **115**, 1927; letters to *Nature*, March 2 and March 30, 1929.

Chapman, Prof. S.—Expected to appear in *Memoirs of Royal Meteorological Society*.

Eccles, Prof. W. H.—Cf. *Journal, Physical Society*, June 15, 1929.

Eddington, Prof. A. S.—Cf. a non-technical account given as a national broadcast lecture on 'Matter in inter-stellar Space,' to be published as a booklet by the B.B.C.; 'Diffused Matter in Space,' Bakerian Lecture, *Proc. Roy. Soc. A*, **111**, p. 424, 1926.

Fowler, Prof. A.—Paper on 'Standard Wave-lengths in the extreme Ultra-violet,' expected to be published in extended form in *Proc. Roy. Soc.*; paper on the 'Spectra of Carbon, Nitrogen, &c.,' cf. *Proc. Roy. Soc. A*, **117**, p. 317; **118**, p. 34; **120**, p. 312; **123**, p. 422; *Journal, Chemical Society*, April 1928.

Rayleigh, Lord—Cf. *Proc. Roy. Soc. A*, **125**, p. 1, 1929.

Rutherford, Sir E.—Cf. letter to *Nature*, March 2, 1929; detailed paper in course of publication.

Sitter, Prof. W. de—On 'Rotation of the Earth,' cf. *Bulletin, Astronomical Institute of the Netherlands*, **4**, nos. 124, 127, and Supplement to *Nature*, 3038; on 'Jupiter's Satellites,' cf. *Annals of Leiden University*, **16**, pts. 2, 4.

Tutton, Dr. A. E. H.—*Phil. Mag.*, p. 195, Aug. 1929.

Tyndall, Prof. A. M.—Cf. *Proc. Physical Society*, **41**, pt. 4, 1929.

Walker, Sir G. T.—On 'Meteorology in Application,' to be published by South African Association for the Advancement of Science.

Wrinch, Dr. Dorothy M.—To be published in *American Journal of Mathematics*; cf. *Phil. Mag.* **50**, 1925; Proc. International Congress of Mathematicians, Bologna, 1928.

SECTION B.

Bassett, Prof. H.—On 'Inter-relationships of Sulphur Acids,' *Journal, Chemical Society*, 1927, pp. 1401-1468; on 'Cobalt Chloride Colour Changes,' to be published in *Journal, Chemical Society*.

Egerton, A.—Cf. 'Mechanism of Combustion' in *Réunion Internationale de Chimie Physique*, Paris, Oct. 1928.

Sidgwick, Dr. N. V.—To be published by South African Association for the Advancement of Science.

SECTION C.

Boswell, Prof. P. G. H.—To be published in *Geological Magazine*.

Dixey, Dr. F.—Expected to be published in *Geological Magazine*.

Suess, Prof. F. E.—Cf. *Anzeiger der Akademie der Wissenschaften in Wien*, mathematisch-naturwissenschaftliche Klass, Sitzung vom 10 Mai, 1929; 'Gedanken zur Tektonik der Schottischen Kaledoniden'; further publication intended in *Geological Magazine* and in *Sitzungsberichte der Akademie der Wissenschaften*, Wien.

SECTION D.

Dixey, Dr. F. A.—To be published by South African Association for the Advancement of Science.

Jenkin, Miss P. M.—Cf. letter in *Nature*, Oct. 12, 1929.

SECTION E.

Cornish, Dr. Vaughan—*South African Architectural Record*, Sept. 1929.

Fleure, Prof. H. J.—To be published in *Scottish Geographical Magazine*.

McCaw, G. T.—Extracts expected to appear in *South African Survey Journal*; report on the Arc of the Meridian in Northern Rhodesia expected to be published in 1931.

Myres, Prof. J. L.—Joint Meeting with Section L, cf. *Geographical Teacher*, 13, p. 285, 1926; *Report, British Association*, 1928, presidential address, Section E.

Newbigin, Dr. M. I.—Expected to be published in *South African Geographical Journal*.

Roxby, Prof. P. M.—*Scottish Geographical Magazine*, Jan. 1930.

SECTION G.

Johnson, Lt.-Col.—*Engineering*, July 26, 1929; cf. leading articles in *Roadless News*, Aug. 1928, Dec. 1928, and following.

Marchant, Prof. E. W.—*Engineering*, Aug. 9, 1929; *The Electrician*, Aug. 9, 1929; *Electrical Review*, Sept. 6, 1929.

Merz, C. H.—*Engineering*, Aug. 2, 1929.

Parsons, Hon. Sir C. A.—*Engineering*, Aug. 16, 1929; *South African Engineering*, Aug. 1929; cf. 'Steam Turbines,' *Proc. World Power Conference*, 1924; 'Steam Turbines,' *Journal*, International Mathematical Congress, 1924; 'Progress in Economy of Turbine Machinery on Land and Sea,' *Proc. North-East Coast Institution of Engineers and Shipbuilders*, 1927; *Engineering*, Jan. 21, 1927.

SECTION H.

Breuil, Abbé.—Cf. Les Peintures Rupestres du Bassin Inférieur de l'Abre, I. Calapata à Cretas (Teruel); II. Cogul (Lerida), *L'Anthropologie*, 1909, pp. 1-21, 9 fig.; Les Peintures Rupestres d'Espagne, III. Los Toricos d'Albarracin (Teruel), *L'Anthropologie*, 1911, pp. 641-648, 3 fig.; IV. Les Abris del Bosque à Alpera (Albacete); V. Tortosilla à Ayora (Valencia), *L'Anthropologie*, 1912, pp. 529-562, 13 fig.; VI. Les Abris Peints du Monte Arabi, près Yecla (Murcie); VII. Nouvelles Roches Peintes de la Région d'Alpera (Albacete); VIII. Les Roches a Figures (Naturalistes de la Région de Velez Blanca (Almeria), *L'Anthropologie*, 1915, pp. 313-336, 10 fig.; Les Peintures Rupestres de la Péninsule Ibérique, XI. Les Roches Peintes de Minateda (Albacete), *L'Anthropologie*, 1920, pp. 1-50, 46 fig.; Gravures Rupestres du Désert Lybique identiques à celles des anciens Bushmens, Inst. Fr. d'Anthr., 18 Novembre 1925, *L'Anthropologie*, 1926, pp. 125-126; Les Peintures Rupestres de la Grotte d'Inezzan (Sahara Central), *L'Anthropologie*, 1926, pp. 429-437; Las Pinturas Rupestres de los Alrededores de Tormon (Teruel), *Boletín de la Real Academia de la Historia*, 90, 1927; Les Gravures Rupestres du Djebel Quenat (Lybie), *Revue Scientifique*, 25 Février, 1928.

Carline, G. R.—To be published in *Bankfield Museum Notes*; cf. 'Primitive Weaving,' *Halifax Courier*, Sept. 5, 1927.

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Fleure, Prof. H. J.—To be published by South African Association for the Advancement of Science.

Frobenius, Dr. L.—*Illustrated London News*, Aug. 24, 1929; *Atlantis*, May 1929.

Gates, Prof. R. R.—Cf. 'Heredity in Man,' chap. 16, London, Constable.

SECTION I.

Joint Meeting with Sections D, K.—Discussion on 'Nature of Life,' to be published in full by the *Cape Times*, Ltd.; Prof. H. Wildon Carr's contribution, cf. articles expected to appear in the *Realist* and in the *Personalist*, University of Southern California, Jan. 1930.

Copeman, Dr. S. Monckton.—Cf. *Journal of Public Health*, Nov. 10, 1928.

Creed, Dr. R. S.—To be published by South African Association for the Advancement of Science.

Mellanby, Prof. E.—Cf. 'Experimental Rickets,' 1921, *Medical Research Council Special Reports Series*, no. 61; 'Experimental Rickets,' 1925, *Medical Research Council Special Reports Series*, no. 93; E. Mellanby and H. N. Green, 'Vitamin A as an Anti-infective Agent,' 1928, *Brit. Med. Journal*, ii, 691; 'Vitamin A as an Anti-infective Agent (its use in the treatment of puerperal septicæmia),' 1929, *Brit. Med. Journal*, i, 984.

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Drummond, Miss M.—Cf. 'Child Psychology,' London, Arnold; 'The Psychology of the Pre-School Child,' Partridge.

Farmer, E.—Cf. 'A Psychological Study of Individual Differences in Accident Rates' (E. Farmer and E. G. Chambers), *Report no. 38*, Industrial Health Research Board, 1926; 'A Study of Personal Qualities in Accident Proneness and Proficiency' (E. Farmer and E. G. Chambers), *Report no. 55*, Industrial Health Research Board, 1929, London, H.M. Stationery Office.

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Saunders, Miss E. R.—Cf. B.A. Report, 1924, 1927 (abstract); *Annals of Botany*, **37**, 1923; **39**, 1925; **41**, 1927; **43**, 1929; *New Phytologist*, **24**, 1925; **27**, 1928; **28**, 1929; *Journal of Roy. Hort. Soc.* **50**, 1925. It is proposed to continue publication in the *Annals of Botany* and *New Phytologist*.

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